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KEITHLEY

Instruction Manual

Model 261

Picoameter Source

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INSTRUCTION MANUAL
MODEL 261
Picoampere Source

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SPECIFICATIONS

OUTPUT: 10^{-14} ampere (10^{-11} ampere full range) to 1.1×10^{-4} ampere, positive or negative, in eight decade ranges.
ACCURACY: Exclusive of input drop considerations.

Range Setting	Span, ampere	Accuracy With 10.00 Setting (Ten-Volt Source Voltage)	Worst-Case With Setting Other than 10.00
10^{-7} to 10^{-5}	10^{-7} to 1.1×10^{-4}	±0.25%	±0.25%
10^{-8}	10^{-8} to 10^{-7}	±0.5%	±0.5%
10^{-9}	10^{-9} to 10^{-8}	±0.6%	±0.8%
10^{-10}	10^{-10} to 10^{9}	±0.6%	±1.1%
10^{-11}	10^{-11} to 10^{10}	±0.6%	±1.3%
10^{-12}	10^{-12} to 10^{-11}	±0.7%	±1.6%
10^{-13}	10^{-14} to 10^{-12}	—	±2.0%

LONG-TERM STABILITY: Will operate within stated specifications for three months after calibration. After three months add 0.15% per month for 10^{-8} through 10^{-12} ampere range setting accuracy specification.
TEMPERATURE COEFFICIENT: ±0.01%/°C, 15°C to 30°C on 10^{-7} to 10^{-5} ampere range settings. Approximately −0.1%/°C on 10^{-12} to 10^{-8} ampere range settings. Exact value for these ranges supplied with instrument.
WARM-UP TIME: 1 hour.

LINE REGULATION: 0.01% for 10% change in line voltage.
SOURCE VOLTAGE: 0 to 11 volts in 0.01-volt steps.
RESOLUTION: 3 significant figures from 10^{-12} ampere to 1.1×10^{-4} ampere.
RANGE RESISTORS: 10^{5} to 10^{12} ohms in decade steps; ±5%.
RANGE RESISTOR ACCURACY: Value given on certificate.
±0.5%; 10^{8} to 10^{12} ohms
±0.1%; 10^{7} to 10^{8} ohms
±0.02%; 10^{5} ohms
OUTPUT ISOLATION: Low to ground: greater than 10^{5} ohms shunted by .001 microfarad.
CERTIFICATION: A Calibration Certificate is furnished including range resistor values, thermal coefficients, temperature and date of calibration. Certification traceable to the National Bureau of Standards is also available.
POWER: 105-125 or 210-250 volts (switch selected), 50-60 Hz, 6 watts.
CONNECTORS: Output: Teflon-insulated UHF type. Low and Ground: Binding posts.
DIMENSIONS, WEIGHT: Style P, 5¼ in. half-rack, overall bench size 6¼ in. high x 9 in. wide x 12 in. deep (155 x 225 x 305 mm); net weight, 9 pounds (3,8 kg).
ACCESSORIES SUPPLIED: Model 2611 Test Cable, 2 feet (0,6 m) long with 2 male UHF connectors.

SECTION 1. GENERAL DESCRIPTION

1-1. GENERAL.

a. The Keithley Model 261 Picoampere Source is a secondary standard for use in calibrating dc picoammeters. Its output is from 10^{-14} ampere to 1.1×10^{-4} ampere in eight decade ranges. The Source has 3-digit resolution for outputs from 10^{-12} to 10^{-4} ampere.

b. Output current accuracy is $\pm 0.25\%$ of setting from 10^{-7} to 1.1×10^{-4} ampere, and ranges to $\pm 1.6\%$ of setting from 10^{-14} to 10^{-12} ampere. These accuracies include high-megohm resistor drift for three months after calibration; input voltage drop considerations (paragraph 2-4) were excluded.

c. The Model 261 is line operated; the low side of the output can be floated to avoid ground loops or for use in ungrounded systems. Current is derived from a variable voltage source and a selectable range resistor. The voltage supply uses solid-state components throughout, and it is highly regulated for stability.

1-2. FEATURES.

a. Source voltage of the Picoampere Source is up to 11 volts, which permits accurate calibration of picoammeters with up to a 10-millivolt input voltage drop without using a correction calculation.

b. The high-megohm resistance standards are selected for stability. Individual temperature coefficients and resistance values are measured and supplied with the instrument.

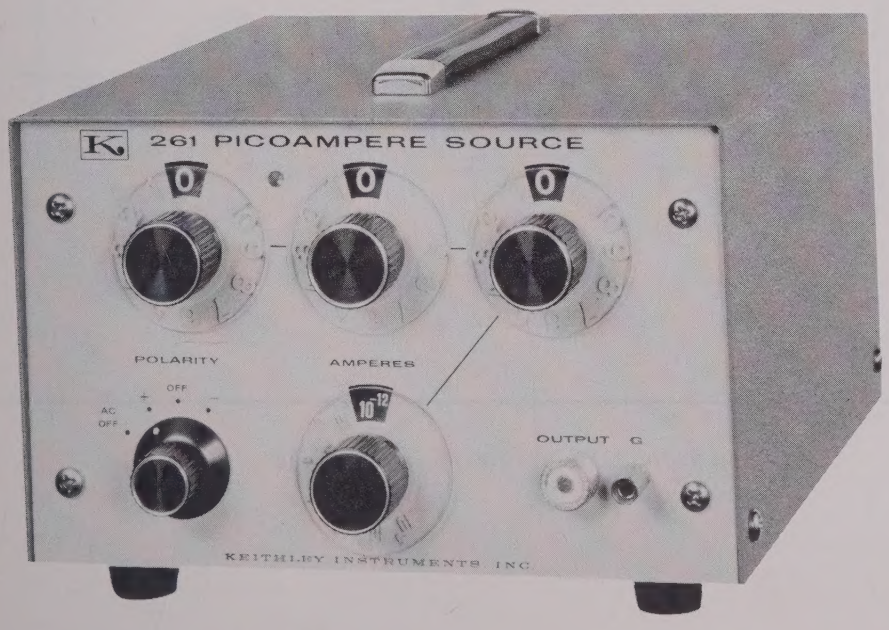


TABLE 1a.
Front Panel Controls

Control	Functional Description	Paragraph
POLARITY Switch (S106)	Sets output polarity for +, -, or OFF.	2-1a
AMPERES Switch (S102)	Sets current in decade steps.	2-1b
Multiplier Switches		2-1c
X1 (S105)	Sets voltage from 1 to 10 volts.	
X.1 (S104)	Sets voltage from .1 to .9 volts.	
X.01 (S103)	Sets voltage from .01 to .1 volts.	
OUTPUT Receptacle (J104)	UHF output connector.	2-1d
Ground (G) (J101)	Case ground.	2-1d

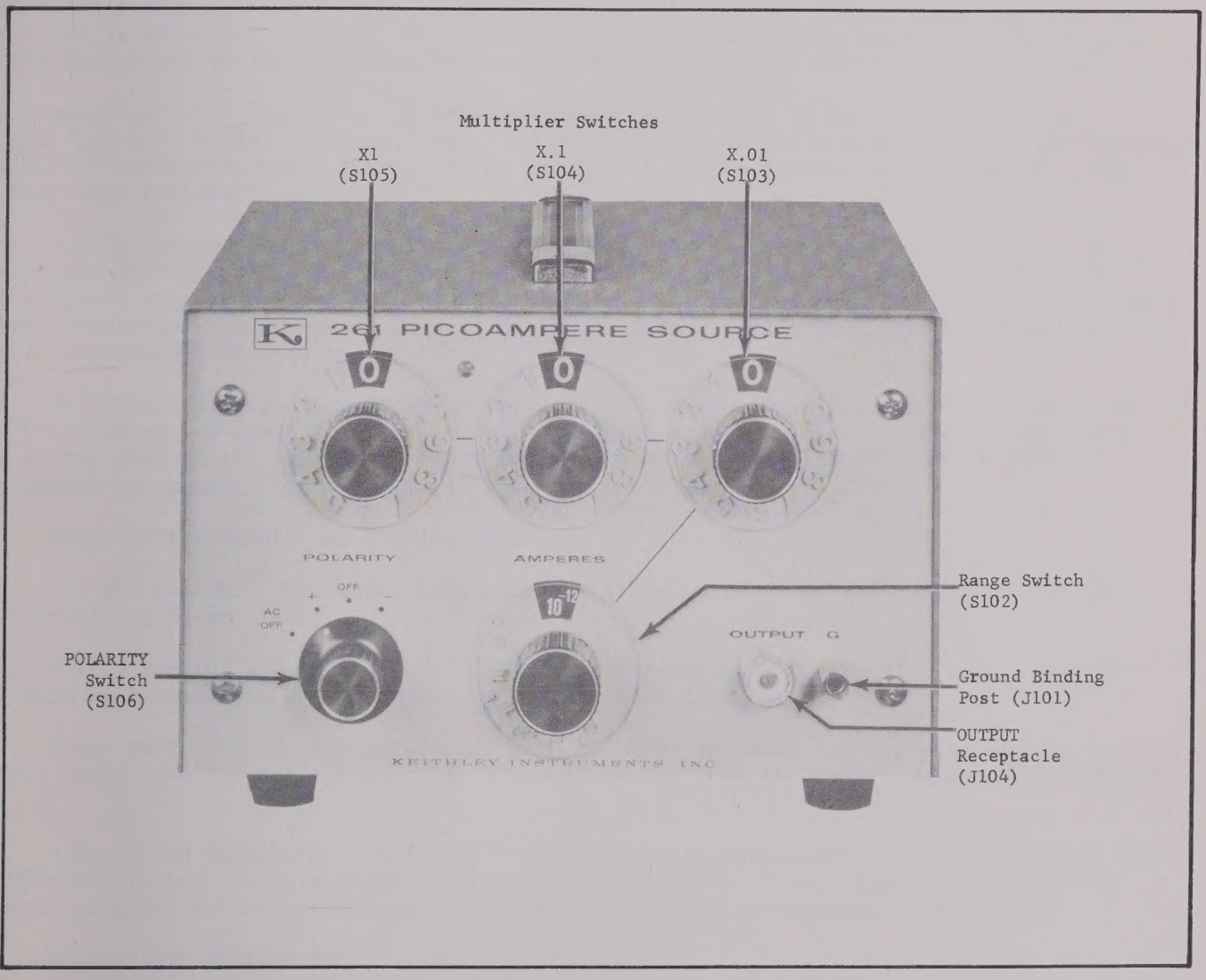


FIGURE 2. Front Panel Controls

SECTION 2. OPERATION

2-1. FRONT PANEL CONTROLS AND TERMINALS. (See Figure 2.)

a. POLARITY Switch. The POLARITY Switch has four positions: the + and - positions provide for either positive or negative current outputs. In the AC OFF setting, the Model 261 power is disconnected. When the Switch is set to OFF, the voltage supply remains on but there is no output current. The output resistance of the instrument for this setting is the reciprocal of the Range Switch setting regardless of the Multiplier Switch settings.

b. Range Switch. The Range or AMPERES Switch selects one of eight decade current ranges from 10^{-5} to 10^{-12} ampere. When the Multiplier Switches are set to 1.00, the Range Switch indicates the output current. The reciprocal of the setting is the nominal value of the range resistor being used.

c. Multiplier Switches. Three switches provide multiplying values for the Range Switch. The illuminated decimal point between the first and second dials is also the pilot lamp. The Switches vary the output with a 3-decade Kelvin-Varley divider. The first (units) and third (hundreths) switches each have 11 positions from 0 to 10; the second (tenths) switch has 10 positions from 0 to 9.

d. OUTPUT Receptacle. The OUTPUT Receptacle is a Teflon-insulated uhf-type connector. The threaded or low side is not connected to chassis ground unless the COM and GND Terminals at the rear of the Source are connected. A chassis ground terminal, G, is next to the OUTPUT Receptacle.

2-2. REAR PANEL CONTROLS AND TERMINALS.

a. 117-234 Switch. The screwdriver-operated slide switch sets the Model 261 for 117 or 234-volt ac power lines.

b. FUSE. For 105-125 volt operation, use a 1/8 ampere, 3 AG slow blow fuse. For 210-250 volt operation, use a 1/16 ampere, 3 AG slow blow fuse.

c. Power Cord. The 3-wire power cord with the NEMA approved 3-prong plug provides a ground connection for the cabinet. An adapter for use from 2-terminal outputs is provided.

d. COM and GND Terminals. The green COM Binding Post is connected to the shield of the OUTPUT Receptacle. The black GND Binding Post is connected to the chassis. A shorting link is provided to connect the two terminals to ground the low-side of the output.

2-3. PRELIMINARY PROCEDURES.

NOTE

Use the Model 2611 Test Cable to connect the Picoampere Source to the picoammeter. The Cable makes connections more convenient and minimizes noise and leakage. Also, the Model 6106 Electrometer Connection Kit contains many items to increase accuracy and convenience during measurements.

a. Check the 117-234 Switch and the Fuse for the proper ac line voltage. Connect the power cord.

b. Set the Model 261 controls as follows:

POLARITY Switch	OFF
Range Switch	Desired current range
Multiplier Switches	1.00

c. Connect the Source to the picoammeter, using the Model 2611 Test Cable. Follow guide points outlined in paragraph 2-5. Floating operation also is given there.

d. Set the POLARITY Switch to + or - to obtain the current of the desired polarity.

2-4. OPERATING PROCEDURES AND ACCURACY CONSIDERATIONS. The Range Switch setting times the Multipler Switch setting gives the Model 261 current output. The accuracy of the output, however, depends upon several factors.

a. Output connections from the Source to the picoammeter are very important, especially for the lower ranges. The accuracy of the current at the Model 261 OUTPUT Receptacle will mean little if poor or improper hookups are made from the Source to the picoammeter.

b. Picoammeter Input Voltage Drop.

1. For specified output accuracy the voltage drop of the picoammeter must be less than 1/1000 of the internal source voltage of the Model 261. The internal source voltage in volts is read directly from the Multiplier Switch setting, regardless of the Range Switch setting. The voltage drop of the picoammeter is a characteristic of that instrument: it can be found in its instruction manual or it must be calculated.

2. For picoammeters with a 1-millivolt or less voltage drop, set the Model 261 Multiplier Switches to 1.00. For a voltage drop between 10 and 1 millivolts, set the Multiplier Switches to 10.00 and set the Range Switch one decade lower. This setting does not affect the Model 261 accuracy for outputs greater than 10^{-8} ampere. For lower outputs see sub-paragraph c below. Note that even for a voltage drop 1/100 of the source voltage, an error of only 1% is added to the specified Picoampere Source accuracy.

c. Setting the Multiplier Switches to 1.00 insures the most accurate output current, given the proper voltage drop/source voltage ratio. Setting the Multiplier Switches to other than 1.00 does not affect the accuracy for outputs greater than 10^{-8} ampere. Below this, an error due to the voltage coefficient of the high-megohm resistors will affect the current output. In all cases, however, the Model 261 output accuracy is at least that of the worst-case accuracy listed in the accuracy specification in paragraph 1-4.

d. When the Model 261 is used on the 10^{-9} to 10^{-12} ranges at other than the calibrated temperature — stated on the Calibration Certificate furnished with the Source — a discrepancy in the output current will occur. On other ranges the effect is not significant.

e. The following paragraphs list ways to avoid introducing calibrating errors and state compensations for these errors. Normally, accuracies of $\pm 0.25\%$ at 10^{-7} ampere to $\pm 0.7\%$ at 10^{-12} ampere are readily obtainable. In those cases where you must deviate from the operating procedures, compensations may be made to increase accuracy. Even without the compensation, though, the accuracy will be as good as or better than the worst-case accuracy specified in paragraph 1-4.

2-5. OUTPUT CONNECTIONS.

NOTE

Make all connections carefully between the Model 261 and picoammeters having fast response speeds. Tie down cables; avoid vibrations. Cable movements cause meter jitter on the 10^{-9} ampere and lower ranges due to capacitance changes.

a. For currents 10^{-8} ampere and less, carefully shield the output connections and the input connection of the picoammeter. Unless the shielding is thorough, any change in the electrostatic field near the input circuitry will cause definite meter disturbances on the picoammeter.

b. Use high resistance, low-loss materials — such as Teflon (recommended), polyethylene or polystyrene — for insulation. The insulation leakage resistance of test fixtures and leads should be several orders of magnitude higher than the internal resistance of the source. If it is not, leakage losses will cause lower readings. Coaxial cables used should be a low-noise type which employ a graphite or other conductive coating between the dielectric and the surrounding shield braid. Amphenol-Borg Electronics Corporation, Microdot, Inc., and Simplex Wire and Cable Company make satisfactory types.

NOTE

Ground loops may occur when equipment connected to the Model 261 has one side of the input grounded. In this case disconnect the shorting link between the Model 261 COM and GND Binding Posts. The low side of the output then floats; output isolation from low to ground is greater than 10^9 ohms shunted by 0.001 microfarad with the link removed.

c. High resistance paths in the output connections do not appreciably reduce the Model 261 current output accuracy if the Source is used with a low input voltage drop or feedback-type picoammeter. (Refer to paragraph 2-6 for picoammeter characteristics.) As an example, the Model 261 is used with a picoammeter with a 1-millivolt drop (Figure 3). The Source is set to 10^{-12} ampere. If the leakage resistance is 10^{12} ohms, the error caused by leakage, R_e, is

$$\frac{0.001 \text{ mv}}{10^{12} \text{ ohms}} = 10^{-15} \text{ ampere}$$

This is 0.1% of the source current, 10^{-12} ampere. Leakage resistance of the Model 2611 Test Cable is nominally greater than 10^{14} ohms.

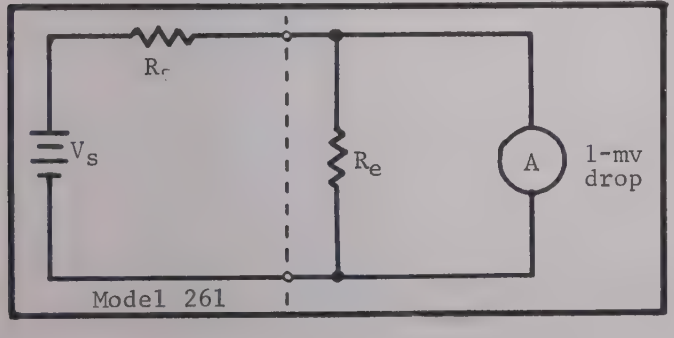


FIGURE 3. High Resistance Paths in Model 261 Output Connections. The Model 261 is shown connected to a picoammeter, A, with a 1-millivolt input drop. The Model 261 is set to 10^{-12} ampere output, so the source voltage, V_s, is 1 volt and the range resistor, R_s, is 10^{12} Ω. Leakage resistance, R_e, is 10^{12} Ω.

Cause of Discrepancy in Output Current	Picoammeter Type	Ranges Affected	Paragraph Reference	Equation to Compensate for Discrepancy
Picoammeter input voltage drop more than 1/1000 of source voltage	Feedback	all	2-7	5
	Shunt-Type High-Impedance	all	2-8	6 or 8
	Shunt-Type Low-Impedance	all	2-9	8
Multiplier Switch on setting other than 1.00 (voltage coefficient)	Feedback	10^{-9} to 10^{-12}	2-10	10 or 11
	Shunt-Type High-Impedance	10^{-9} to 10^{-12}	2-10	12 or 13
	Shunt-Type Low-Impedance	10^{-9} to 10^{-12}	2-10	10 or 11
Model 261 ambient temperature differs from that stated in Calibration Certificate	all	10^{-8} to 10^{-14}	2-11	14

TABLE 1. Causes of Discrepancy in Model 261 Output Current and Correction Index. The Table summarizes compensations which may be made to correct the output current. If these are not made, the current accuracy will at least be that of the worst-case accuracy stated in paragraph 1-4. Making the correction increases accuracy.

2-6. INPUT VOLTAGE DROP FOR FEEDBACK AND SHUNT-TYPE PICOAMMETERS.

a. The output current accuracy is specified under the assumption that the picoammeter input voltage drop is less than 1/1000 of the Model 261 source voltage. Most feedback electrometer and chopper picoammeters will easily meet this condition. Any error caused by the picoammeter voltage drop may be eliminated by calculation if the voltage drop is known. However, only a 1% error is added if the voltage drop is 1/100 of the source voltage.

b. The general magnitude of the voltage drop is dependent upon the type of circuit the picoammeter uses. Feedback types have a low input voltage drop — approximately 1 millivolt or less. Shunt types generally have a relatively large input voltage drop (about 10 millivolts or more). However, some low-current shunt-type ammeters can be calibrated as if they were the feedback type. To help determine the type of picoammeter under calibration, a brief description of the circuits follows. Also, see Table 2.

1. Feedback-Type Picoammeter. The feedback-type picoammeter is basically an operational amplifier with a feedback resistor connected between the input and the output as shown in Figure 4. If the amplifier input current, I_g, is small compared to the input current, I_i, an expression for the amplifier output voltage, V_o, for an input current of I_i is:

$$V_o = I_i R_f \frac{k}{1-k} \qquad \text{Equation 1.}$$

where R_f is the value in ohms of the feedback resistor;
k is the amplifier gain.

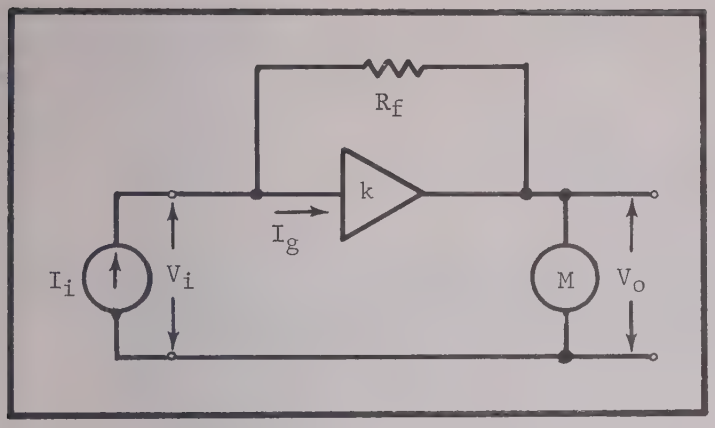


FIGURE 4. Simplified Circuit Diagram of Feedback-Type Picoammeter. R_f is the feedback resistor around the picoammeter amplifier; k is the amplifier gain. V_i is the input voltage drop and V_o is the output voltage. M is the meter. I_g is the amplifier input current. The input signal to the picoammeter is I_i.

If $k \gg 0$, $V_o \approx -I_i R_f$.
The output voltage may be used to drive either a recorder or the meter, M. The input voltage drop, V_i, is

$$V_i = -V_o/k \qquad \text{Equation 2.}$$

Typical values for the above parameters for a picoammeter are:

Input current to picoammeter, $I_i = 10^{-12}$ ampere
Amplifier gain, $k = 10^4$
Picoammeter feedback resistor, $R_f = 10^{12}$ ohms
Amplifier output voltage, $V_o = 1$ volt
Input voltage drop, $V_i = 100$ microvolts

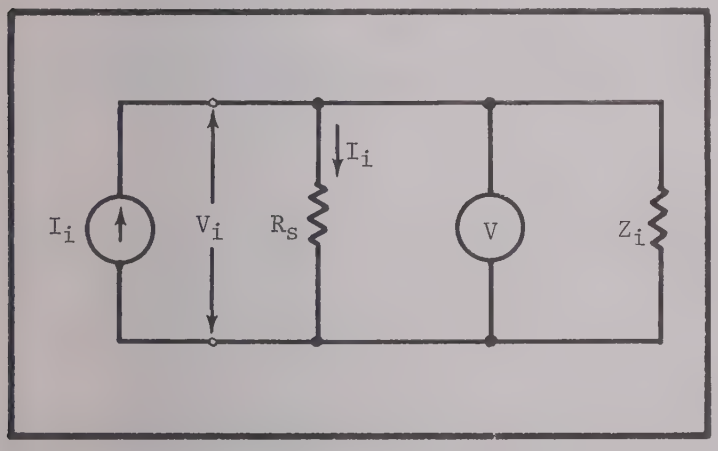


FIGURE 5. Simplified Circuit Diagram of Shunt-Type Picoammeter. R_s is the shunt resistor across the voltmeter, V. Z_i is the input impedance of the voltmeter. V_i is the picoammeter input voltage drop. The input signal to the picoammeter is I_i.

2. Shunt-Type Picoammeter. This type consists of a voltmeter, V, calibrated in amperes, which responds to the IR drop across a shunt resistor, R_s. Refer to Figure 5. The voltmeter can be one of two kinds:

a high impedance voltmeter, such as an electrometer, which has an extremely high input impedance, Z_i;

or a low impedance voltmeter.

a) The input voltage drop, $I_i R_s$, of a picoammeter using a high-impedance voltmeter is usually 1 millivolt or more, due to voltmeter sensitivity limitations. Rise

time is usually slow, possibly several minutes for very low current levels. Typical values are:

Input current to picoammeter, $I_i = 10^{-12}$ ampere
Picoammeter shunt resistor, $R_s = 10^{10}$ ohms
Voltmeter input impedance, $Z_i = 10^{14}$ ohms
Input voltage drop, V_i = 10 millivolts.

b) The circuit of a shunt-type picoammeter using a low-impedance voltmeter is essentially the same as Figure 5, except a more sensitive but lower input impedance voltmeter is used. A lower input voltage drop results, but response speed and maximum current sensitivity are usually less. The voltage drop is $I_i R_s$. Typical values are:

Input current to picoammeter, $I_i = 10^{-10}$ ampere
Picoammeter shunt resistance, $R_s = 10^6$ ohms
Voltmeter input impedance, $Z_i = 9 \times 10^7$ ohms
Input voltage drop, V_i = 100 microvolts

2-7. COMPENSATION FOR INPUT VOLTAGE DROP OF FEEDBACK-TYPE PICOAMMETERS.

a. Errors caused by picoammeter input voltage drops of 1 millivolt or less are negligible for Model 261 outputs between 1.1×10^{-4} and 10^{-11} ampere. Following the instructions in paragraph 2-4 will bring the output current accuracy to between ±0.25% and ±0.7% as specified in paragraph 1-4.

b. Calculating the Error. When either the picoammeter voltage drop or input resistance is known, use either equation 3 or 4 to determine the error. Tables 3 and 4 list the

1. Feedback-Type Picoammeters:

   Keithley Models 409, 410, and 414 Picoammeters
   Keithley Models 412 and 413A Log Picoammeters
   Keithley Models 416 and 417 High-Speed Picoammeters
   Keithley Model 418A Remote Ranging Picoammeter
   *Keithley Models 600A, 601, 602, 610B and 621 Electrometers (in fast mode)

2. Shunt-Type Picoammeters using high-impedance voltmeters:

   Keithley Models 600A, 601, 602, 610B, 621 Electrometers (normal mode)
   Keithley Model 200B Electrometer when used with Model 2008 Decade Shunt

3. Shunt-Type Picoammeters using low-impedance voltmeter:

   Keithley Models 150B and 153 Microvolt-Ammeters

* When calibrating these instruments on the low current ranges, use the normal mode and set the Multiplier Switch to 10 millivolts.

TABLE 2. Partial List of Picoammeters by Circuit Type. Generally, types 1 and 3 have low input voltage drops (1 mv and less), type 2 has a relatively high input voltage drop. Refer to paragraph 2-6.

voltage drops for Keithley current measuring instruments. Note these are maximum values; actual values will be less.

When the voltage drop is known:

$$E_{vd} = \frac{V_i \times 100}{V_s} \qquad \text{Equation 3.}$$

where E_{vd} is the percent of error due to the picoammeter input voltage drop;
V_i is the picoammeter input voltage drop in volts;
V_s is the Model 261 source voltage, read directly in volts from the Multiplier Switch settings.

When the input resistance is known:

$$E_{vd} = \frac{R_i \times 100}{R_s} \qquad \text{Equation 4.}$$

where R_i is the picoammeter input resistance in ohms;
R_s is the Model 261 source resistance, which is the reciprocal of the Range Switch setting.

NOTE

Values of V_s and R_s are within ±5% when read from the Model 261 Multiplier and Range Switches for all ranges except the 10^{-5} ampere range, on which the values are within ±0.25%. For the correction equations, this accuracy is sufficient.

c. Compensating Equation. If the voltage drop is precisely known, the actual Model 261 output current can be calculated. Equation 5 gives the output current value if the input voltage drop is the only significant source of error.

$$I_a = I_s \ (V_s - V_i) \qquad \text{Equation 5.}$$

where I_a is the actual output current from the Model 261;
I_s is the Range Switch setting (reciprocal of range resistor value);
V_s is the Model 261 source voltage, read directly in volts from the Multiplier Switch setting;
V_i is the picoammeter input voltage drop in volts.

Keithley Model	Maximum Input Voltage Drop, millivolts	Keithley Model	Maximum Input Voltage Drop, millivolts
409	1.0	414	5.0
410	5.0	416	1.0
412	5.0	417	1.0
413A	5.0	418A	1.0

TABLE 3. Maximum Voltage Drop for Keithley Picoammeters. Note the voltage drop given is the maximum at full-scale deflection; use equation 1 to figure exact values. The voltage drop is essentially constant for all ranges.

Keithley Model	Maximum Input Voltage Drop, millivolts
600A	1.0
610A, Multiplier Switch set to 1 or less	1.0
610A, Multiplier Switch set to 100 through 3	5
610B, Multiplier Switch set to .1 or less	0.01
610B, Multiplier Switch set to 10 through .3	1.0
610B, Multiplier Switch set to 100 or 30	2.0
620	1.0
621	1.0

TABLE 4. Maximum Input Voltage Drop for Keithley Electrometers. The above Electrometers, set to the fast mode, operate as feedback-type picoammeters. Note the voltage drop given is the maximum; use equation 1 to figure exact values.

2-8. COMPENSATION FOR INPUT VOLTAGE DROP OF SHUNT-TYPE HIGH-IMPEDANCE PICOAMMETERS.

a. As long as the voltage drop is less than 1/1000 of the source voltage, errors due to the input voltage drop of this type picoammeter will not affect the Model 261 accuracy. Following the instructions in paragraph 2-4 will bring the accuracy of the Model 261 output current to between ±0.25% and ±0.7% as specified in paragraph 1-4. The chief point is setting the Multiplier Switches to higher values, so that the source voltage is 1000 times the picoammeter input voltage drop. If the meter sensitivity is adjustable, use the most sensitive range to obtain the smallest voltage drop.

NOTE

If the instrument can measure current on either a feedback-type or shunt-type circuit, calibrate on the feedback circuit. For example, calibrate the Keithley Model 610B Electrometer in the fast mode (feedback circuit) not the normal mode (shunt).

b. Calculating the Error. Equation 3 determines the error when the picoammeter input voltage drop is known. The voltage drop is easily found, since the meter or other readout device indicates the voltage drop on these type picoammeters.

c. Compensating Equation.

1. Since the picoammeter voltage drop can be found, the Model 261 output current can be corrected. Equation 6 gives the output current value if the input voltage drop is the only significant source of error and if the voltage drop is less than 1/10 the source voltage.

$$I_a = I_s (V_s - V_i) \qquad \text{Equation 6.}$$

where I_a is the actual output current from the Model 261;
I_s is the Range Switch setting (reciprocal of range resistor value);
V_s is the Model 261 source voltage, read directly in volts from the Multiplier Switch setting;
V_i is the picoammeter input voltage drop in volts, read from the meter.

Using this correction, accuracy is ±0.5% +(Model 261 accuracy). This error results from the factory calibration method used for the Model 261 that adjusts the source voltage from that indicated to match the range resistor used. (See paragraph 6-6.)

2. For greater accuracy or if the input drop is more than 0.1 times the source voltage, use equation 8 to compensate for the error. The following equation is based on the calibration procedures.

$$V_S' = V_S \left(\frac{R_S'}{1/I_S} \right) = V_S R_S' I_S \qquad \text{Equation 7.}$$

where V_S' is the actual source voltage;
V_S is the Model 261 source voltage, read directly in volts from the Multiplier Switch setting;
R_S' is the actual source resistance — from the Calibration Certificate supplied with the Model 261;
I_S is the Model 261 Range Switch setting (reciprocal of range resistor value).

Using equation 7 in equation 6 and substituting V_S' for V_S,

$$I_a = I_S (I_S V_S R_S' - V_i) \qquad \text{Equation 8.}$$

where I_a is the actual output current from the Model 261;
V_i is the picoammeter input voltage drop in volts read from the meter.

Using equation 8 completely compensates for the error due to the input voltage drop.

2-9. COMPENSATION FOR INPUT VOLTAGE DROP OF SHUNT-TYPE LOW-IMPEDANCE PICOAMMETERS.

a. For the most part, the voltage drop for this type picoammeter is about the equivalent of that of the feedback-type picoammeter — 1 millivolt or less. Following the directions in paragraph 2-4 will assure Model 261 output currents within the specified accuracy.

b. To compensate for output current differences caused by input voltage drops, use equation 8. This calculation will be precise, since the voltage drop is read directly from the picoammeter meter.

2-10. COMPENSATION FOR VOLTAGE COEFFICIENT.

a. On Range Switch settings from 10^{-9} to 10^{-12}, inaccuracies caused by the voltage coefficient of high-megohm resistors become significant in certain cases. The voltage coefficient does not affect current output when the Range Switch is set to 10^{-8} or higher. When the Multiplier Switches are set to 1.00, no discrepancy is caused on any range. Other Multiplier Switch settings on the 10^{-9} to 10^{-12} ranges, however, will introduce some error. Note that the output current accuracy will be at least that listed in the second column — worst-case accuracy — of the Accuracy Specification in paragraph 1-4. The specified accuracy includes the effects of the voltage coefficient for the 10^{-13} and 10^{-14} ampere ranges.

Range Switch Setting	Multiplier Switch Setting (source voltage in volts)	Voltage Coefficient (add to output current) %/volt
10^{-12}	1.00 to 3.00	+0.4
10^{-12}	3.01 to 11.00	+0.02
10^{-11}	1.00 to 3.00	+0.15
10^{-11}	3.01 to 11.00	+0.04
10^{-10}	1.00 to 3.00	+0.1
10^{-10}	3.01 to 11.00	+0.015
10^{-9}	1.00 to 3.00	+0.1
10^{-9}	3.01 to 11.00	+0.01

TABLE 5. Voltage Coefficients for Various Range Switch Settings. The effect on the output current caused by the range resistor voltage coefficient is not significant for other Range Switch settings. The accuracy of the voltage coefficients stated is ±10%.

b. Compensating Equation: Feedback-Type and Shunt-Type Low-Impedance Picoammeters. The effect of the high-megohm voltage coefficient on the Model 261 current output can be calculated using equation 9. This gives the current value measured by the picoammeter if the effect of voltage coefficient is the only significant source of error.

$$I_a = I_s \left[\frac{V_s}{1-.01\ VC\ (V_s-1)} \right] \qquad \text{Equation 9.}$$

where I_a is the actual or compensated Model 261 output current;
I_s is the Range Switch setting (reciprocal of range resistor value);
V_s is the source voltage in volts, read directly from the Multiplier Switches;
VC is the voltage coefficient for the settings of the Range Switch and the Multiplier Switches (Table 5). It is multiplied by .01, since the Table value is a percent.

Using the Taylor Series Expansion* for Equation 9:

$$I_a = V_s\ I_s \left[1 + .01\ VC\ (V_s - 1)\right] \qquad \text{Equation 10.}$$

For Multiplier Switch setting more than 3.00, make two corrections — from 1 to 3 volts and from 3 to N volts. See equation 11.

$$I_a = V_s\ I_s \left[1 + (.01 \times VC_{1-3} \times 2) + .01 \times VC_{3-11}\ (V_s-3)\right] \qquad \text{Equation 11.}$$

VC_{1-3} is the voltage coefficient from 1 to 3 volts;
VC_{3-11} is the voltage coefficient from 3 to 11 volts.

* Taylor Series Expansion: $\frac{a}{1-x} \approx a\ (1+x)$ for $x \ll 1$

Example 1: The Model 261 is set to 3.00×10^{-12} ampere. Using equation 10, the actual current output is:

$$I_a = 3.00 \times 10^{-12} \left[1 + .01 \times .4 (3.00-1)\right]$$

$$I_a = 3.024 \times 10^{-12} \text{ ampere.}$$

This value differs from the dial value slightly:

$$\frac{0.024}{3.00} = 0.008 \text{ or } 0.8\%$$

Without making this correction, the accuracy would be 0.7% (accuracy at 10^{-12}) plus 0.8% or 1.5%. This is less than the specified worst-case accuracy of ±1.6%.

Example 2: The Model 261 is set to 5.00×10^{-12} ampere. Using equation 11, the actual current output is:

$$I_a = 5.00 \times 10^{-12} \left[1 + (.01 \times .4 \times 2) + .01 \times .02 (5.00-3.00)\right]$$

$$I_a = 5.042 \times 10^{-12} \text{ ampere.}$$

This value differs from the dial value slightly: 0.81%. Without making this correction, the accuracy would be 1.51%, which is under the specified worst-case accuracy of ±1.6%.

c. Compensating Equations: Shunt-Type High-Impedance Picoammeters. The calculation is essentially the same as described in the previous subparagraph. The difference is a correction for the source voltage in equations 10 and 11. If the difference between the input voltage drop and the source voltage is less than 3, equation 10 becomes

$$I_a = (V_s - V_i) I_s \left[1 + .01 \text{ VC } (V_s - V_i - 1)\right] \qquad \text{Equation 12.}$$

where I_a is the actual or compensated Model 261 output current;
V_s is the source voltage in volts, read directly from the Multiplier Switches;
V_i is the picoammeter input voltage drop in volts;
I_s is the Range Switch setting (reciprocal of the range resistor value);
VC is the voltage coefficient for the settings of the Range Switch and the Multiplier Switches (Table 5). It is multiplied by .01, since the Table value is a percent.

If the difference between the input voltage drop and the source voltage is more than 3, equation 11 becomes

$$I_a = (V_s - V_i) I_s \left[1 + (.01 \times VC_{1-3} \times 2) + .01 \times VC_{3-11} (V_s - V_i - 3)\right] \qquad \text{Equation 13.}$$

where VC_{1-3} is the voltage coefficient from 1 to 3 volts;
VC_{3-11} is the voltage coefficient from 3 to 11 volts.

2-11. COMPENSATION FOR TEMPERATURE COEFFICIENT.

a. When the Model 261 is used on Range Switch settings above 10^{-8} or at the temperature listed on the Calibration Certificate, the room temperature will not affect the output current. For Range Switch settings from 10^{-9} to 10^{-12}, the value of the range resistor decreases as the temperature increases. Therefore, the Model 261 current output will be more than the value desired.

b. The Model 261 is calibrated at a specified temperature ±0.5°C, which is stated on the Calibration Certificate, for the 10^{-9} to 10^{-12} ranges. The Certificate also lists the temperature coefficients by range. These range from -0.06%/°C to 0.15%/°C for the 10^{-9} through 10^{-12} ampere ranges respectively.

NOTE

The stated temperature coefficient holds for an ambient temperature variation of 23°C ±5°C.

c. Compensating Equation. The effect of temperature differences on the Model 261 current output can be calculated using equation 14. This gives the output current value if the temperature effect is the only significant source of error.

$$I_a = I_s \left[\frac{1}{1 - (T_2 - T_1) \frac{tc}{100}} \right] \approx I_s \left[(i + (T_2 - T_1) \times .01 \times tc \right] \quad \text{Equation 14.}$$

where I_a is the actual or compensated Model 261 current output;
I_s is the indicated current output (Range Switch setting times the Multiplier Switch settings);
T_2 is the room temperature in °C;
T_1 is the calibration temperature in °C;
tc is the temperature coefficient of the range resistor in %/°C given on the Calibration Certificate.

SECTION 3. APPLICATIONS

3-1. GENERAL. This Section discusses ways of using the Model 261 Picoampere Source. Three applications are particularly well suited for the instrument: current suppression, galvanometric measurements and ohmmeter calibration. These do not exhaust the possibilities of using the Model 261; instead, they illustrate the techniques used for the most common applications other than in calibrating picoammeters.

3-2. CURRENT SUPPRESSION.

a. The Model 261 can be used to buckout or suppress steady background currents so that a picoammeter can measure small variations in the signal. For instance, using this system enables a picoammeter to observe small fluctuations in a phototube output, while the Model 261 suppresses the dark currents.

b. Because of its wide use, the Keithley Model 610C Electrometer is used to illustrate the application. With the Models 261 and 610C, suppression up to 1000 times full scale is possible. Suppression up to at least 100 times is possible with most picoammeters.

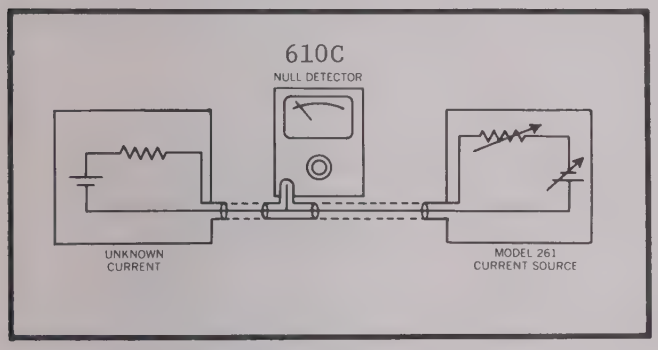


FIGURE 6. Circuit Diagram for Current Suppression. Connect the coaxial T fitting directly to the Model 610C INPUT receptacle. Use the Model 2611 Cable for connecting instruments.

c. Connect the Models 261 and 610C to the unknown current as shown in Figure 6. Make sure the connections are well made; use the Model 2611 Test Cable or other coaxial cable. Refer to paragraph 2-5.

d. Operate the Model 261 as previously described in paragraphs 2-3 and 2-4. Set the Model 610C FEEDBACK Switch to FAST; this makes the Electrometer a feedback-type picoammeter. Set the Model 261 POLARITY Switch to the polarity opposite that of the unknown current. Set the current output to a value as near as possible to that of the current to be suppressed. Set the Model 610C to the least sensitive ampere range; gradually increase sensitivity until a null is reached. Keep its Multiplier Switch on 1.

e. Set both the Model 261 and 610C Range Switches to the same setting. If the Electrometer is set to a lower range, the Model 261 source resistance will divide the Model 610C feedback. This will impair the Electrometer's zero stability. Switch the Multiplier Switch gradually from 1 to .001. In this last setting, the Model 610C current sensitivity is 1000 times the unknown current.

f. The procedures with other instruments are the same. Check the picoammeter's specifications to find any circuit limitations. Set the picoammeter to the best sensitivity possible.

3-3. GALVANOMETRIC MEASUREMENTS.

a. In this application, the Model 261 bucks out the unknown current and a picoammeter serves as a null detector. Currents as low as 10^{-12} ampere can be measured to ±0.7%, using the Keithley Model 610B Electrometer as a null detector.

b. Follow the same procedures for this measurement as given in paragraph 3-2. In use, galvanometric measurements are a special case of current suppression.

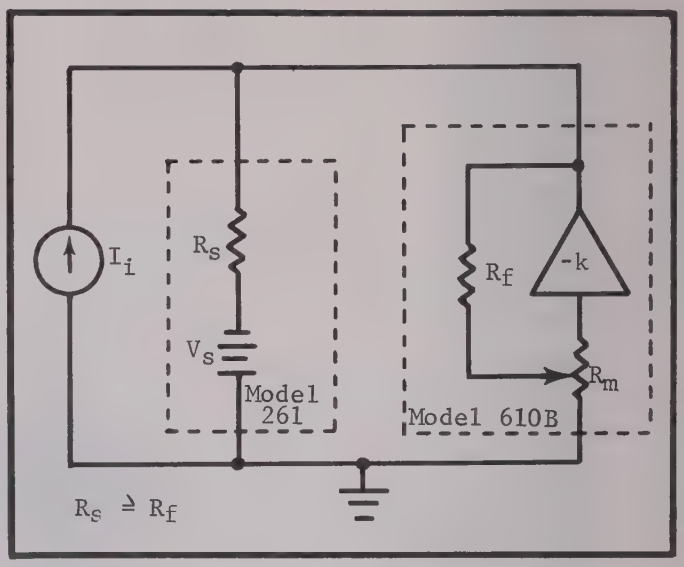


FIGURE 7. Circuit for Galvanometric Measurements. R_s is the Model 261 source resistance; V_s, the source voltage. R_f is the picoammeter feedback resistor; k, the amplifier gain; R_m, the Multiplier Switch, I_i is the unknown current.

3-4. OHMMETER CALIBRATION.

a. The Model 261 contains calibrated resistance standards, which make it very useful for checking high resistance measuring instruments. The Range Switch indicates the reciprocal of the nominal value of the range resistor. The exact resistor value is on the Calibration Certificate supplied with each Source.

b. Procedures.

1. Set the Model 261 POLARITY Switch to OFF and the Multiplier Switches to 0.00. Set the Range Switch to the reciprocal of the ohms range to be checked. Connect the ohmmeter to the Source OUTPUT Receptacle using coaxial cable. Follow the hookup procedures outlined in paragraph 2-5.

2. Carefully shield connections above 10^8 ohms. Use guarded connections for resistances 10^9 ohms and more. See Figure 8. A guarded connection to the range resistor will eliminate the shunting effect of cable and connector resistance. For example, using the 10^{10} ohm range, a 10^{12} ohm leakage resistance will add an error of 1%. To make the connection, set the CAL-OPERATE Switch (S101, Figure 10) to CAL. Remove the link between the GND and COM Terminals of the Source. The outer shell of the OUTPUT Receptacle is the guard and the G Binding Post beside it is connected to the low side of the range resistor.

3. Record the ohmmeter measurement and compare it to the values on the Model 261 Calibration Certificate. The 10^{12}, 10^{11}, 10^{10} and 10^9 ohm resistors decrease in value at the rate of approximately 0.15% per month after factory calibration. The 10^8 ohm resistor increases in value at the same rate. Determine a more exact rate by interpolating the resistance change on the Calibration Certificate for the three months prior to shipment.

c. The voltage developed by the ohmmeter across the 10^{12}, 10^{11}, 10^{10} and 10^9 ohm resistors will have some effect on the resistance value due to the voltage coefficient. Refer to Table 5 for the voltage coefficients by ranges, and the effect can be calculated. The Calibration Certificate lists the potential used in measuring the range resistors.

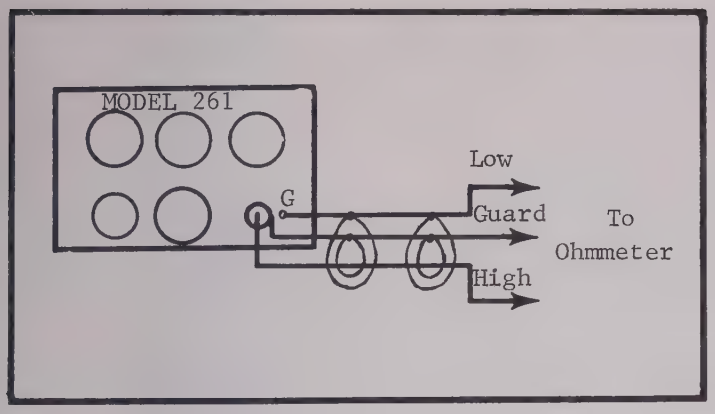


FIGURE 8. Guarded Circuit for Ohmmeter Calibration. This circuit is recommended for resistances of 10^9 ohms and more.

SECTION 4. CIRCUIT DESCRIPTION

4-1. GENERAL.

a. The Keithley Model 261 Picoampere Source is basically a precision variable voltage source in series with a selectable range resistor. The circuit provides currents from 10^{-14} to 1.1×10^{-4} ampere when used with a low input drop picoammeter.

b. The variable voltage source uses a stable (±0.05%/yr) zener regulated solid-state voltage supply and a 3-dial Kelvin-Varley divider which has ±0.1% accuracy. The Multiplier Switches, S103 to S105, contain the divider resistors.

c. The Range Switch also programs the voltage supply output for each individual current range to provide a means of calibration.

NOTE

Refer to Schematic Diagram 18323E for circuit designations.

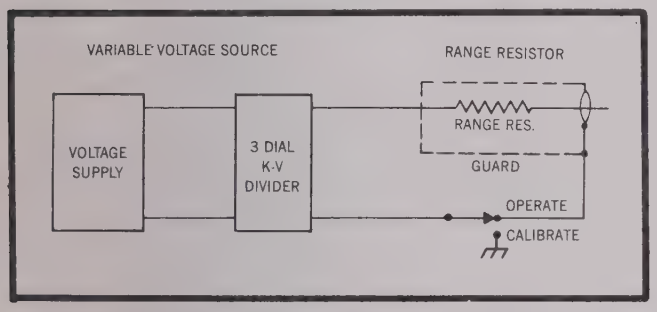


FIGURE 9. Simplified Model 261 Block Diagram.

4-2. RANGE RESISTORS.

a. The range resistors, R101 through R108, are mounted on a specially designed rotary switch, Range Switch S102, using Teflon insulation, and silver and gold-plated contacts. The 10^{-5} ampere range resistor, R101, is a 0.02% wirewound resistor. 1% carbon film resistors, R102 to R104, are used on the 10^{-6} to 10^{-8} ranges. The most sensitive ranges use glass sealed high-megohm resistors. The high-megohm resistors are carefully selected after a 3-month stability test. Capacitor C101 and resistors R109, R110 and R111 form a damping network to compensate for capacity across the high-megohm resistors, R106 to R108. The network eliminates high current transients when the Picoampere Source is turned on. The voltage source connects through one deck of switch S102 to the range calibration controls, R113 through R119.

b. The Range Switch, OUTPUT Receptacle J104 and the range resistors are encased in a floating shield which is normally connected to the low side of the output. The shield is also connected as a guard for resistance measurements or for calibration when Switch S101 is in the CAL position.

4-3. KELVIN-VARLEY DIVIDER. The Kelvin-Varley divider uses 0.1% precision wirewound resistors, R120 through R152, to divide the 11.0 volts from the voltage supply to the value selected with the Multiplier Switches.

4-4. VOLTAGE SUPPLY.

a. The voltage supply operates from either 117 or 234 volts, 50-1000 cps to furnish a stable 11.0 volts with 0.01% line stability for a 10% change in line voltage.

b. The power transformer, T201, is specially constructed and shielded to provide better than 10^9 ohm insulation shunted by 0.001-microfarad isolation from the secondary to ground or line.

c. The 15-volt rms output from the power transformer, T201, is full-wave rectified by diodes D202 and D203, and then is filtered by capacitor C202 to approximately 17 volts dc.

d. To obtain a stable, accurate voltage, the output of the series transistor regulator, Q202, is regulated by comparing a sample voltage from dividers R211, R210, R201 and one of the resistors R112 to R119 to zener diode reference, D207. If a voltage difference exists, it is amplified by a differential amplifier consisting of transistors Q204 and Q205. The signal if further amplified by transistor Q203. The output of Q203 is applied to the Darlington pair, Q201 and Q202, to nullify input and load variations. Capacitor C203 prevents high-frequency oscillations. The 11-volt regulator output is applied to the Kelvin-Varley divider through the POLARITY Switch, S106.

e. Transistor Q203 operates at a high gain by connecting its collector load to a negative regulated supply. The circuit permits linear operation of transistor Q202 with widely varying input voltages. To supply Q203, one side of the secondary of T201 is half-wave rectified and filtered by diode D201 and capacitor C201 respectively. Resistor R202 and zener diode D204 regulate this voltage to a stable -6 volts, referred to the collector of transistor Q202.

f. Resistors R204 and R205 and diode D205 provide current overload protection. Excessive current drawn from the power supply causes an increased voltage drop across resistor R204, which forward biases diode D205, thus preventing the collector of transistor Q203 from going more negative. Since the collector voltage cannot rise, further amplification is prevented and, therefore, further current increase is prevented.

SECTION 5. SERVICING

5-1. GENERAL. Section 5 contains the maintenance and troubleshooting procedures for the Model 261 Picoampere Source. It is recommended that these procedures be followed as closely as possible to maintain the accuracy of the instrument.

5-2. SERVICING SCHEDULE.

a. The Model 261 requires no periodic maintenance beyond the normal care required of high-quality electronic equipment. No part should need replacement under ordinary use except the pilot lamp or the fuse.

b. Check the value of the high-megohm resistors, R104 through R108, every three months. If necessary, recalibrate the Source to assure specified accuracy; see Section 6. Either the user or Keithley Instruments, Inc., can perform the calibration.

5-3. PARTS REPLACEMENT.

a. The Replaceable Parts List in Section 8 describes the electrical components of the Picoampere Source. Replace components only as necessary. Use only reliable replacements which meet the specifications.

b. The range resistors, R104 through R108 (Figure 12), are specially selected and aged to assure the specified Model 261 accuracy for three months. In normal use they do not need replacement. If it is necessary, however, order them from Keithley Instruments, Inc., only. Use the Keithley Part Number given in the Replaceable Parts List. In an emergency, these resistors may be obtained from another distributor, but their stability cannot be guaranteed. In either case, recalibrate the Model 261 after replacing any range resistor.

NOTE

When replacing the range resistors, R104 through R108, do not touch the glass body. Contamination of the specially coated glass insulation will occur, and leakage will result.

5-4. TROUBLESHOOTING.

a. The procedures which follow give instructions for repairing troubles which might occur in the Model 261. Use the procedures outlined and use only specified replacement parts. Table 6 lists equipment recommended for troubleshooting. If the trouble cannot be readily located or repaired, Keithley Instruments, Inc., can service the instrument at its complete service facilities. Contact your nearest representative.

Instrument	Use
Keithley Model 172 or another dc voltmeter, with minimum 100-megohm input resistance, 0.1% accuracy, range from one to 300 volts.	Circuit checking.

TABLE 6. Equipment Recommended for Model 261 Troubleshooting. Use these instruments or their equivalent.

Difficulty	Probable Cause	Solution
No current output on all ranges	Defective voltage supply	Check Q202 and D208 for "open"
	Defective Kelvin-Varley divider	Check S103 through S106; check R120 through R152
No current output on one range	Defective range resistor	Check corresponding range resistor for open circuit
Output too high on all ranges	Defective voltage supply	Check Q202 for short
Output too high on one range	Defective range resistor	Check corresponding range resistor

TABLE 7. Model 261 Troubleshooting.

b. Table 7 contains the more common troubles which might occur. If the repairs indicated in the Table do not clear up the trouble, find the difficulty through a circuit-by circuit check, such as given in paragraph 5-5. Refer to the circuit description in Section 4 to find the more critical components and to determine their function in the circuit The complete circuit schematic diagram, 18323E, is found in Section 8.

5-5. PROCEDURES TO GUIDE TROUBLESHOOTING.

a. If the instrument will not operate, check the fuse, line cord and power source. If these are all found satisfactory, use the following procedures to isolate the trouble.

b. The schematic diagram indicates all the transistor terminal voltages referenced to J202. Check the Notes on the diagram for the settings used.

c. Voltage Supply.

1. Set the POLARITY Switch to + and connect the dc voltmeter between the red test jack, J202, and the emitter of transistor Q202 (Figure 11). The voltage should be -11.6 volts.

2. If the voltage is not -11.6 volts, measure the voltage at the collector of transistor Q202. It should be 17 volts ±20%. Absence of this voltage indicates the regulator circuitry is not operating or transistor Q202 is defective.

3. Measure the voltage at the anode of diode D204 (Figure 11). It should be -17.1 volts ±10%. If this bootstrap voltage is not sufficient, transistor Q203 (Figure 11) will not operate and transistors Q201 and Q202 will be cutoff.

4. Check the reference amplifier and amplifier stage using the schematic voltage values as a guide.

SECTION 6. CALIBRATION

6-1. GENERAL.

a. The following procedures are recommended for calibrating and adjusting the Model 261. Use the equipment recommended in Table 8. If proper facilities are not available or if difficulty is encountered, contact Keithley Instruments, Inc., or its representative to arrange for factory calibration.

b. Calibration is done in three steps. The voltage supply is adjusted to furnish an accurate potential (paragraphs 6-3 and 6-4). The range resistors are measured with a megohm bridge to verify their values (paragraph 6-5). Then, the supply voltage is set on each range with separate internal adjustments so that the output current corresponds to the dial reading (paragraph 6-6). Calibrate in this order.

c. If the Model 261 is not within specifications after the calibration and adjustments, follow the troubleshooting procedures or contact Keithley Instruments, Inc., or its nearest representative.

NOTE

Certification traceable to the National Bureau of Standards is available for the Model 261 from Keithley Instruments, Inc.

6-2. CALIBRATION SCHEDULE. Calibrate the Model 261 every three months to adjust for even small changes in the value of components. Also, recalibrate after replacing any transistors, Kelvin-Varley divider resistors or range resistors.

6-3. VOLTAGE SUPPLY ADJUSTMENT.

a. This adjustment sets the potential applied by the voltage supply to the Kelvin-Varley dividers. Normally, checking the output value is sufficient, unless components of the supply are replaced.

b. Prodecures.

1. Connect the Model 174 Digital Multimeter across the Kelvin-Varley divider. Connect the positive lead to the grey-white wire on the X.01 Switch, S103, and the negative lead to the black-blue wire on the X1 Switch, S105 (Figure 10).

Instrument	Use
Electro Scientific Industries Model 242A Precision Resistance Measuring System	Verify range resistor value for 10^{-5} ampere range
Keithley Instruments Model 515A Megohm Bridge and Model 2612 Calibration Cable	Verify range resistor values for 10^{-6} to 10^{-12} ampere ranges.
Keithley Instruments Model 174 Digital Multimeter. Must read 10 volts ±5 mv.	Adjust voltage supply, range potentiometers and check potential across Kelvin-Varley dividers

TABLE 8. Equipment Recommended for Model 261 Calibration. Use these instruments or their equivalents.

Control	Circuit Desig.	Fig. Ref.	Refer to Paragraph
10^{-6} Range Calibration	R113	10	6-6
10^{-7} Range Calibration	R114	10	6-6
10^{-8} Range Calibration	R115	10	6-6
10^{-9} Range Calibration	R116	10	6-6
10^{-10} Range Calibration	R117	10	6-6
10^{-11} Range Calibration	R118	10	6-6
10^{-12} Range Calibration	R119	10	6-6
10^{-5} Range Calibration	R210	10	6-3, 6-6
Calibrate-Operate Control	S101	10	6-5, 6-6 3-4

TABLE 9. Model 261 Internal Controls. The table lists all internal controls, the figure picturing the location, and the paragraph describing the adjustment.

2. Set the CAL-OPERATE Switch S201 (Figure 10) to OPERATE. Set the Model 261 Range Switch to 10^{-5}; set the POLARITY Switch to +. Set the Multiplier Switches to 10.00.

3. The Model 174 should read ±5 millivolts. Adjust potentiometer R210 (Figure 10) for this output. This potentiometer will be readjusted for correct operation after checking the multiplier switch setting and high megohm resistors. See Sec. 6-6 b3 (PG28).

6-4. VERIFICATION OF MULTIPLIER SWITCH SETTINGS. This verification checks the divided potential from the voltage supply. Keep the Model 174 connected as in paragraph 6-3. Set the Multiplier Switches to 0.00. Then switch each Multiplier Switch through every setting, keeping the other two Switches at 0. The potential for each setting is listed in Table 10. Readings must be within the tolerance for the setting.

Multiplier Switch Setting	Voltage Reading	Tolerance	Multiplier Switch Setting	Voltage Reading	Tolerance
10.00	10 volts	±5 mv	0.40	0.4 volt	±0.84 mV
9.00	9 volts	±9 mv	0.30	0.3 volt	±0.64 mv
8.00	8 volts	±8 mv	0.20	0.2 volt	±0.44 mv
7.00	7 volts	±7 mv	0.10	0.1 volt	±0.24 mv
6.00	6 volts	±6 mv	0.00	0.0 volt	±60µv
5.00	5 volts	±5 mv	0.09	0.09 volt	±310µv
4.00	4 volts	±4 mv	0.08	0.08 volt	±280µv
3.00	3 volts	±3 mv	0.07	0.07 volt	±250µv
2.00	2 volts	±2 mv	0.06	0.06 volt	±220µv
1.00	1 volt	±1 mv	0.05	0.05 volt	±190µv
0.00	0 volt	±100µv			
0.90	0.9 volt	±1.84 mv	0.04	0.04 volt	±160µv
0.80	0.8 volt	±1.64 mv	0.03	0.03 volt	±130µv
0.70	0.7 volt	±1.44 mv	0.02	0.02 volt	±100µv
0.60	0.6 volt	±1.24 mv	0.01	0.01 volt	±100µv
0.50	0.5 volt	±1.04 mv	0.00	0.00 volt	±60µv

TABLE 10. Voltage for Multiplier Switch Settings. Refer to paragraph 6-4 for verification procedures. The 100 microvolts at 0.00 is the residual voltage.

6-5. VERIFICATION OF HIGH MEGOHM RESISTORS.

a. The following procedure outlines the method used at factory calibration to measure the value of the high-megohm range resistors. Keithley Instruments, Inc., specifies the Picoampere Source will be within specifications for three months after it has calibrated the instrument. The inherent drift of the high megohm resistors sets the time limit. If the user performs the calibration, it is very important that he use the finest procedures followed by Standards Laboratories.

b. Procedures.

1. Disconnect the Model 261 power cord from the power source; remove the link from the COM Binding Post on the rear panel. Set the CAL-OPERATE Switch (Figure 10) to CAL. The CAL-OPERATE Switch is a 2-position slide switch. In CAL position, the low side of the range resistor is connected to chassis ground, and the low side of the OUTPUT Receptacle (threaded shell) is connected as a guard between the high side of the output and ground.

2. Calibrate the Keithley Model 515A High Megohm Bridge per its instruction manual.

3. Connect the Model 261 OUTPUT Receptacle to the Model 515A using the Model 2612 Calibration Cable. Use the Model 515A for all ranges except 10^{-5} ampere. For this range, use the ESI Model 242A since it has the necessary accuracy at this resistance.

NOTE

Make sure the Cable will not be moved or allowed to vibrate during the tests.

4. Set the Bridge controls to the values listed in Table 11. Record the values measured to use for range calibration (paragraph 6-6). Table 11 lists the accuracy obtainable for the measurement.

Model 261 Range Switch Setting	Model 261 Resistance Value (ohms)	Bridge Setting	Bridge Potential Setting (volts)	Accuracy of Measurement
$*10^{-5}$	$*10^{5}$ ±0.02%	* 1 x 10^{5}	* 0.9	±0.02%
10^{-6}	10^{6} ±1%	10 x 10^{5}	10	±0.1%
10^{-7}	10^{7} ±1%	10 x 10^{6}	10	±0.1%
10^{-8}	10^{8} ±2%	10 x 10^{7}	10	±0.5%
10^{-9}	10^{9} ±5%	10 x 10^{8}	10	±0.5%
10^{-10}	10^{10} ±5%	10 x 10^{9}	10	±0.5%
10^{-11}	10^{11} ±5%	10 x 10^{10}	10	±0.5%
10^{-12}	10^{12} ±5%	10 x 10^{11}	10	±0.5%

TABLE 11. Settings for Range Resistor Verification. Refer to paragraph 6-5 for procedures. The Keithley Model 515A is used for all ranges except the 10^{-5} ampere (*), for which the ESI 242A is used. Bridge potential settings are nominal. Actual potential is on the Calibration Certificate.

6-6. RANGE CALIBRATION.

a. Calibrate the ranges after performing the previous procedures in this Section, paragraphs 6-3 to 6-5. Range calibration is based on all other adjustments and verifications being complete and accurate. Perform this calibration any time the voltage supply is adjusted or if any Kelvin-Varley resistor or range resistor is replaced.

b. Procedures. The basis of this calibration is I = V/R. The range potential is adjusted to correspond to the exact range resistor value, so that the current produced is equal to one times the range.

1. Set the Model 261 CAL-OPERATE Switch to OPERATE. Connect the Picoampere Source to the proper line source. Connect the Model 174 Digital Multimeter across the Kelvin-Varley divider. Connect the positive lead to the grey-white wire on the X.01 Switch, S103, and the negative lead to the black-blue wire on the X1 Switch, S105 (Figure 10).

2. Set the Model 261 controls to:

POLARITY Switch	+
Range Switch	10^{-5}
Multiplier Switches	10.00

3. Adjust the 10^{-5} CAL Potentiometer, R210 (Figure 10), for 10.012 volts ±5 millivolts when read on the Model 174. Setting the voltage 12 millivolts high compensates for any loading errors on the 10^{-5} ampere range.

4. Set the Multiplier Dials to 1.00; switch the Model 261 through all ranges. Use the internal potentiometer for each range to set the range potential to R volt ± the tolerance listed in Table 12. R is the exact resistor value (paragraph 6-5).

Example: The 10^{-11} range resistor is measured (paragraph 6-5) and its value is 1.019×10^{11} ohms. The range potential is now adjusted when the Range Switch is set to 10^{-11} and the Multiplier Switches to 10.000. Using Table 12, potentiometer R118 is set so the Model 174 Voltmeter reads 10.190 volts ±5 millivolts.

Multiplier Switch Setting	Range Switch Setting	Set Range Potentiometer	To Exact Value of Range Resistor on	Tolerance
10.00	10^{-6}	R113	10^{-6} Range	±5 mv
10.00	10^{-7}	R114	10^{-7} Range	±5 mv
10.00	10^{-8}	R115	10^{-8} Range	±5 mv
10.00	10^{-9}	R116	10^{-9} Range	±5 mv
10.00	10^{-10}	R117	10^{-10} Range	±5 mv
10.00	10^{-11}	R118	10^{-11} Range	±5 mv
10.00	10^{-12}	R119	10^{-12} Range	±5 mv

TABLE 12. Range Calibration. Refer to paragraph 6-6. When the Model 261 Multiplier and Range Switches are set as above, adjust the corresponding potentiometer to the range resistor value recorded in paragraph 6-5.

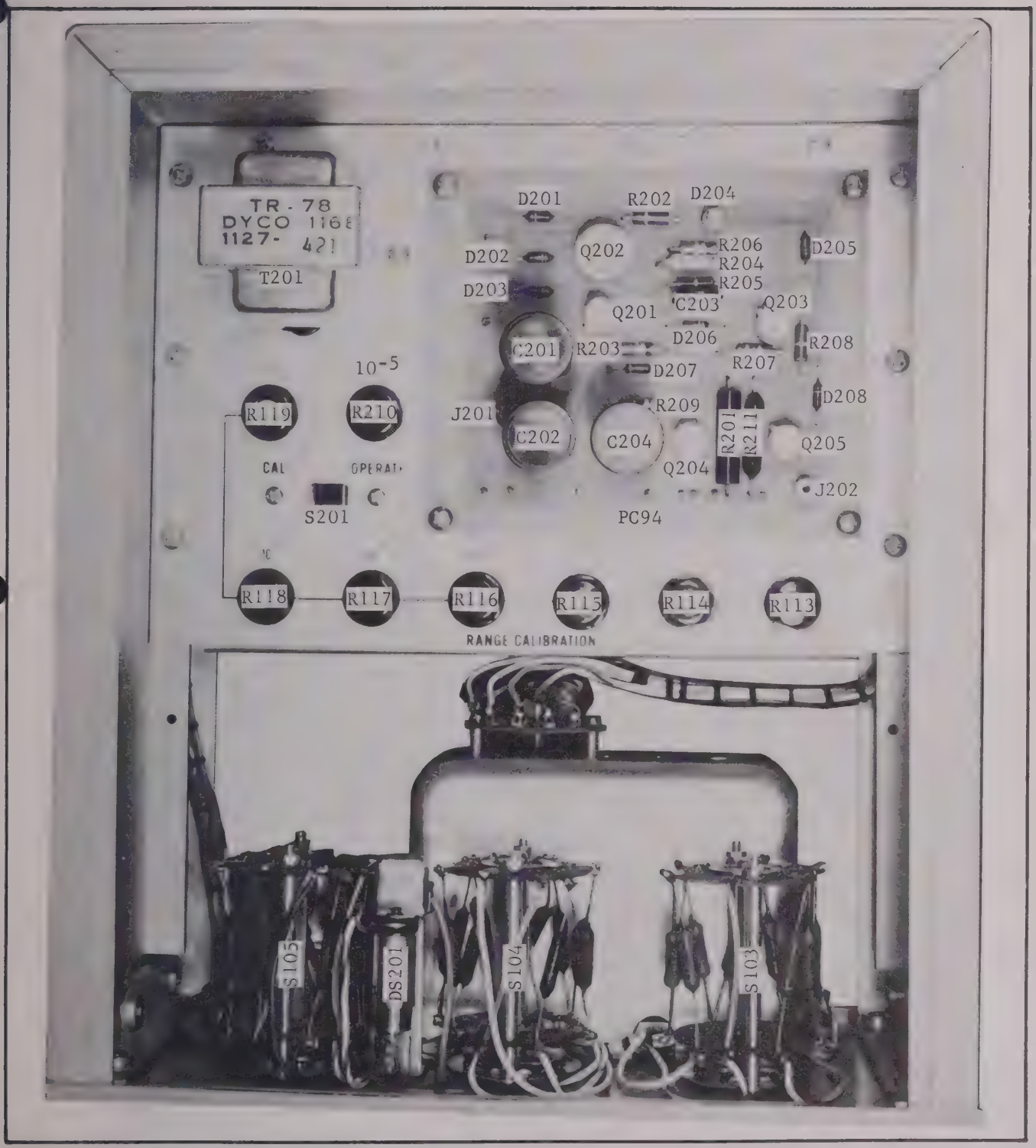


FIGURE 10. Chassis, Top View

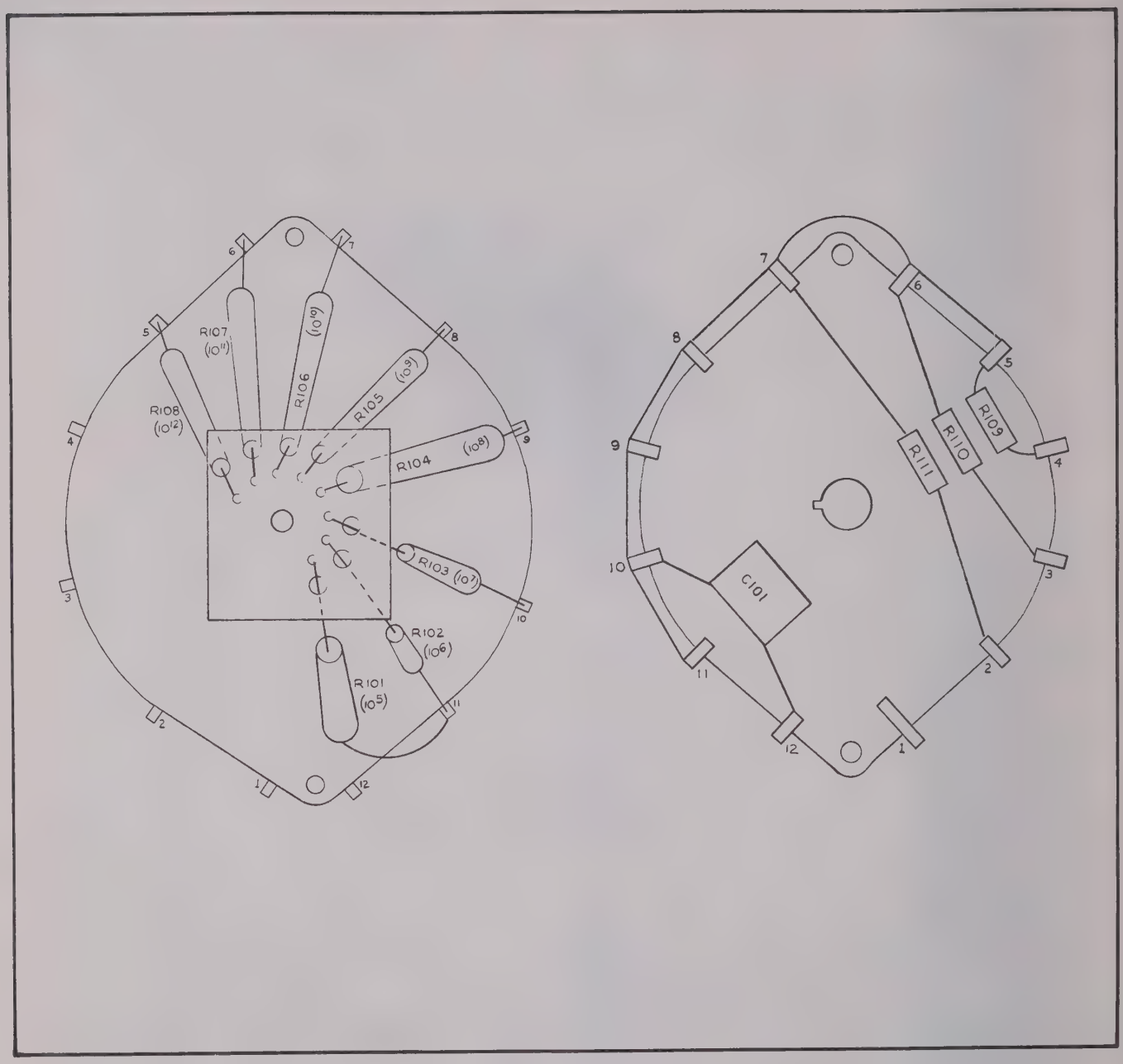


FIGURE 11. AMPERES Range Switch, S102.

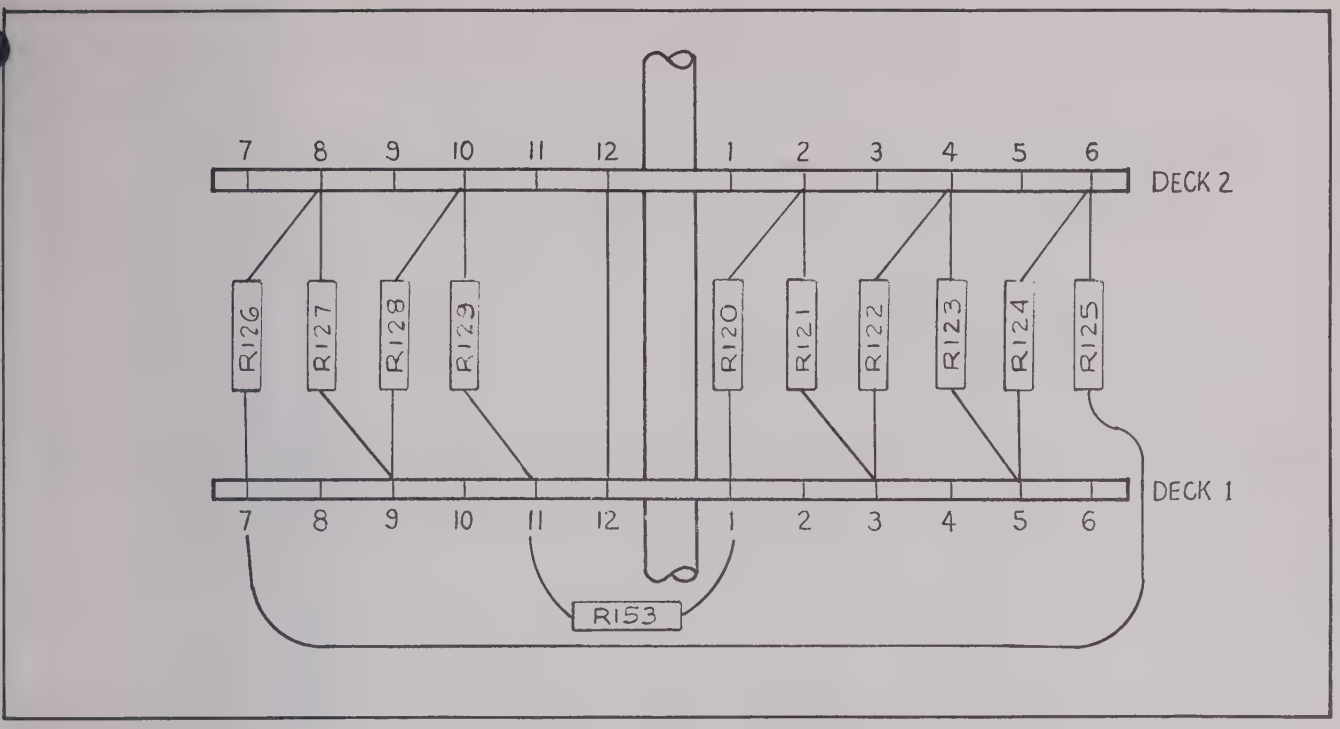


FIGURE 12. Multiplier Switch, S103.

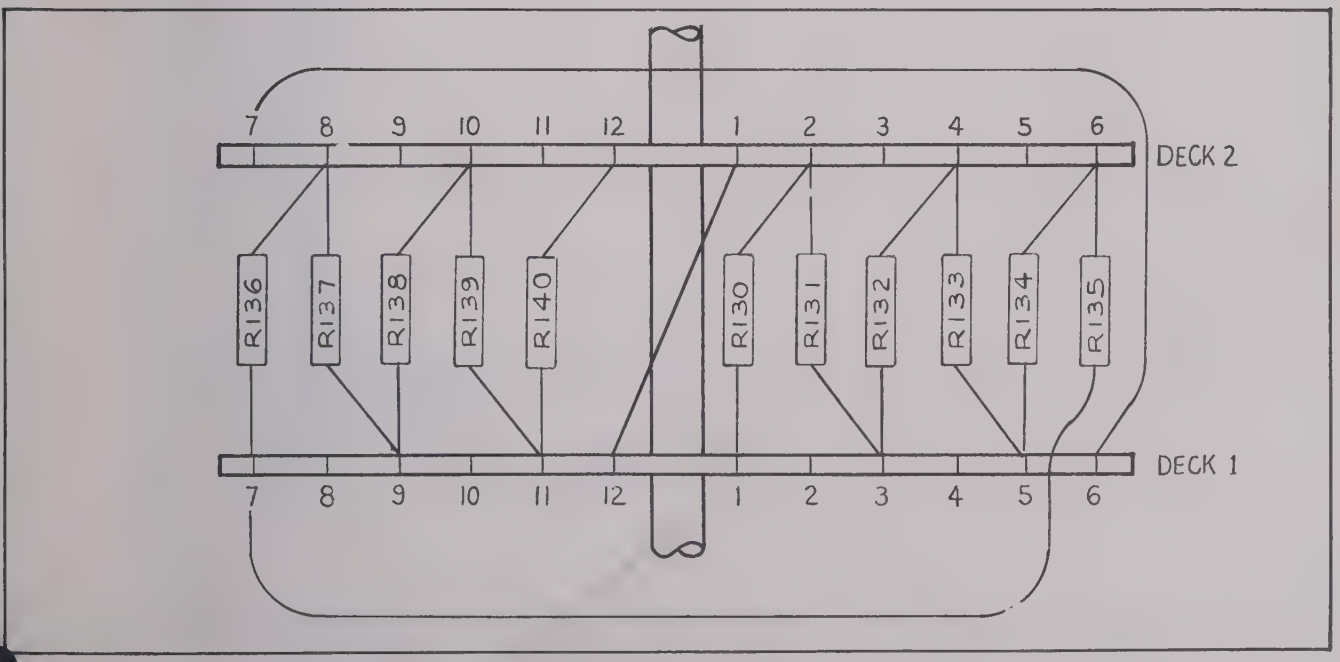


FIGURE 13. Multiplier Switch, S104.

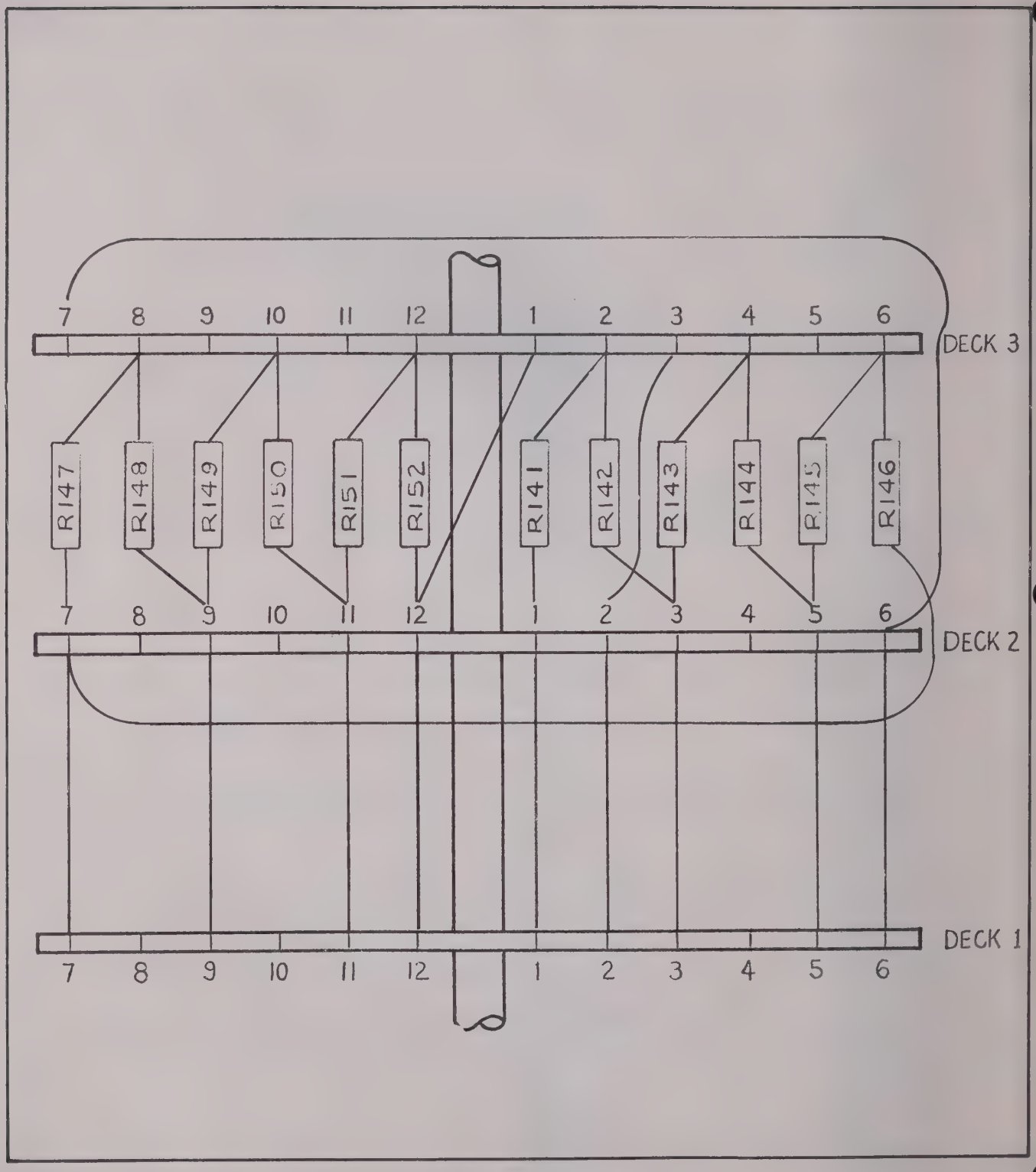


FIGURE 14. Multiplier Switch, S105

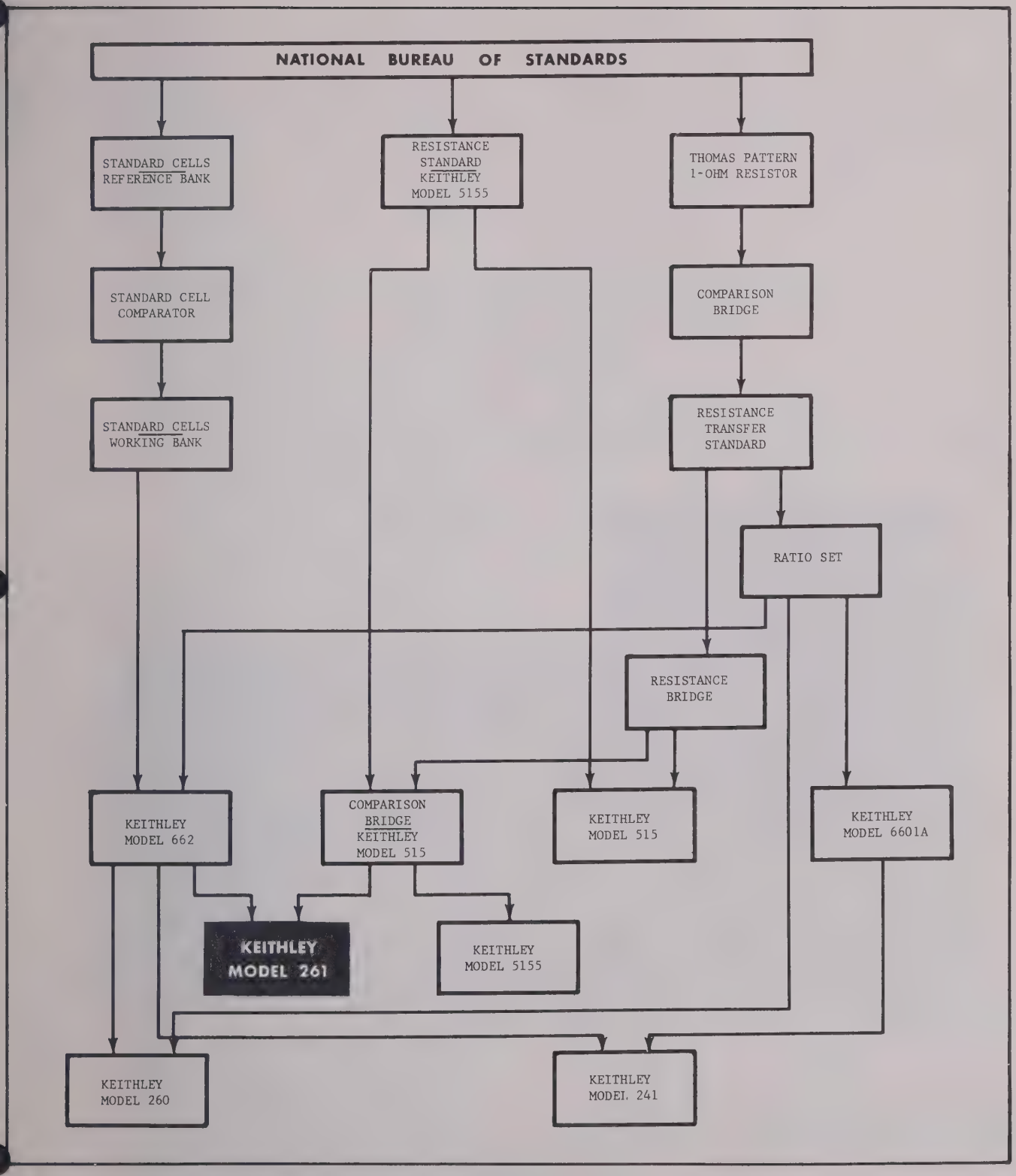


FIGURE 15. Calibration Traceability Chart

SECTION 7. APPLICATIONS

7-1. GENERAL. The following Keithley accessories can be used with the Model 261 to provide additional convenience and versatility.

7-2. OPERATING INSTRUCTIONS. A separate Instruction Manual is supplied with each accessory giving complete operating information.

Model 6106 Electrometer Connection Kit

Description:

The Model 6106 contains a group of the most useful leads and adapters for low current measurements. All components are housed in a rugged carrying case with individual compartments.

Parts List:

Description	Item No.	Keithley Part No.
Cable, 30", UHF to clips	1	19072C
Cable, 24", UHF to UHF	2	18265C
Connector, UHF to UHF	3	CS-5
Adaptor, UHF to BNC	4	CS-115
Adaptor, UHF to BNC	5	CS-172
Adaptor Tee, UHF to UHF	6	CS-171
Adaptor, Binding Post	7	19071B

The two cables (Items 1 and 2) are coaxial shielded leads useful for connections where low noise is essential. The 24" cable (Item 2) can be used to interconnect two instruments having UHF receptacles. The 30" cable (Item 1) can be used to connect to the circuit under test through the use of clip leads. A binding post adapter gives easy access to the electrometer "high" terminal. Two UHF female couplers (Item 3) permit cables to be connected together. The UHF "tee' connector simplifies galvanometric current measurement when using a current source and electrometer or picoammeter. Adapters (Items 4 and 5) are useful for conversion from UHF to BNC terminations.

Model 3004 Dual Bench Mounting Kit

Description:

The Model 3004 is a bench mounting kit with overall dimensions 5-1/2 inches high x 17-1/2 inches wide x 10 inches deep. A single top cover is provided with convenient handles.

Application:

The Model 3004 converts two half-rack instruments (size 5-1/2 inches high x 8-3/4 inches wide x 10 inches deep) to a single bench unit with wrap around cover.

Parts List:

Item No.	Description	Qty	Keithley Part No.
1	Cover Assembly	1	18555B
2	Connecting Plate	1	17454A
3	Connecting Plate	1	19126A
4	Screw, #10x1/2 Hex	4	—
5	Screw, #10x1/2 SH	8	—

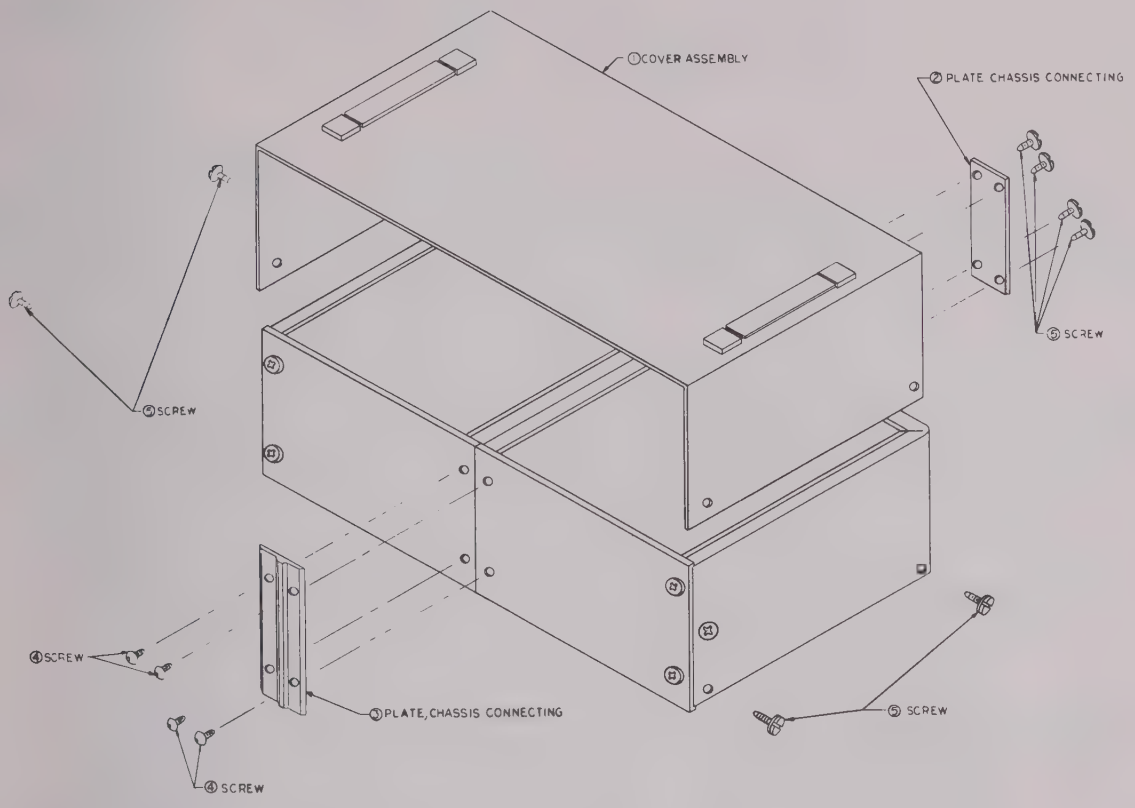


FIGURE 17. Bench Mounting (Model 3004).

Model 4003A Rack Mounting Kit

Description:

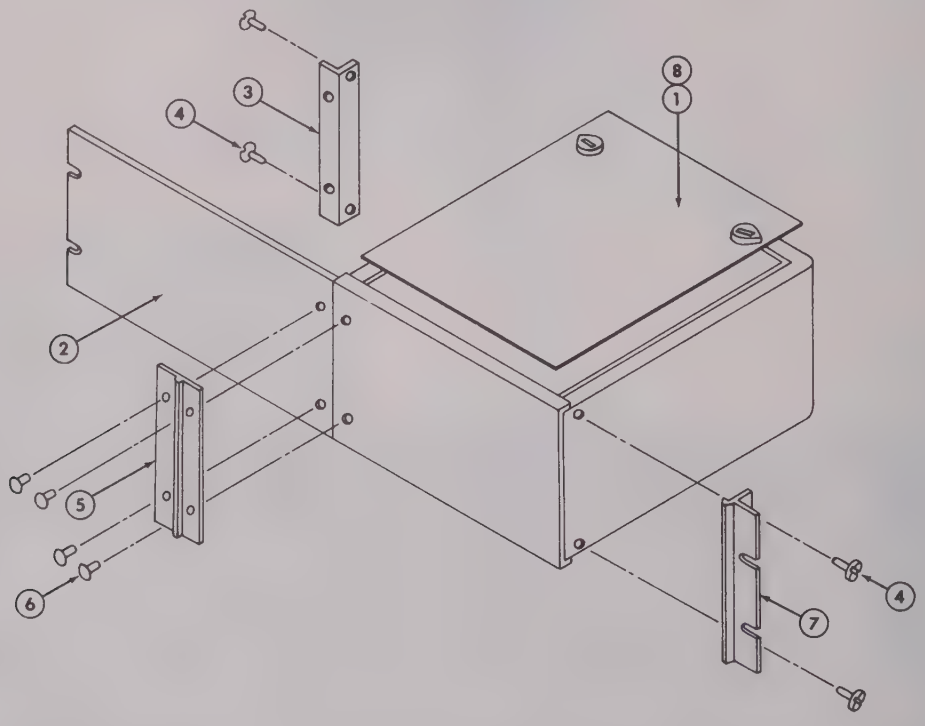
The Model 4003A is a rack mounting kit with overall dimensions, 5-1/4 inches high x 19 inches wide. Two top covers are provided for use with either 10 inch or 13 inch deep instruments.

Application:

The Model 4003A converts the instrument from bench mounting to rack mounting. It is suitable for mounting one instrument in one-half of a standard 19-inch rack.

Parts List:

Item No.	Description	Qty. Per Assembly	Keithley Part No.
1	Top Cover, 10"	1	18554B
2	Panel Adapter Plate	1	17452B
3	Angle Support	1	17476A
4	Screw,#10 x 3/8"	4	---
5	Connecting Plate	1	19126A
6	Screw, #10 x 1/2"	4	---
7	Angle	1	14624B
8	Top Cover, 13"	1	20015B



Model 4004A Dual Rack Mounting Kit

Description:

The Model 4004A is a rack mounting kit with overall dimensions, 5-1/4 inches high x 19 inches wide. Two top covers are provided for use with either 10 inch or 13 inch deep instruments.

Application:

The Model 4004A converts the instrument from bench mounting to rack mounting. It is suitable for mounting two instruments in a standard 19-inch rack.

Parts List:

Item No.	Description	Qty. Per Assembly	Keithley Part No.
1	Top Cover, 10"	2	18554B
4	Screw, #10 x 1/2	8	---
5	Connecting Plate	1	19126A
6	Screw, #10 x 1/2	4	---
7	Angle	2	14624B
8	Top Cover, 13"	2	20015B
9	Zee Bracket	1	19144A
10	Plate (not shown)	1	17454A

SECTION 8. REPLACEABLE PARTS

8-1. REPLACEABLE PARTS LIST. The Replaceable Parts List describes the components of the Models 261 and 2611. The List gives the circuit designation, the part description, a suggested manufacturer, the manufacturer's part number and the Keithley Part Number. The last column indicates the figure picturing the part. The name and address of the manufacturers listed in the "Mfg. Code" column are in Table 18.

8-2. HOW TO ORDER PARTS.

a. For parts orders, include the instrument's model and serial number, the Keithley Part Number, the circuit designation and a description of the part. All structural parts and those parts coded for Keithley manufacture (80164) must be ordered from Keithley Instruments, Inc. In ordering a part not listed in the Replaceable Parts List, completely describe the part, its function and its location.

b. Order parts through your nearest Keithley representative or the Sales Service Department, Keithley Instruments, Inc.

amp	ampere	Mil. No.	Military Type Number
		My	Mylar
CerD	Ceramic, Disc		
Comp	Composition	Ω	ohm
DCb	Deposited Carbon	p	pico (10^{-12})
EAl	Electrolytic, Aluminum	Ref.	Reference
f	farad	μ	micro (10^{-6})
Fig.	Figure		
		v	volt
k	kilo (10^{3})	Var	Variable
M or meg	mega (10^{6} or megohms)	w	watt
m	milli (10^{-3})	WW	Wirewound
Mfg.	Manufacturer	WWVar	Wirewound Variable

TABLE 17. Abbreviations and Symbols.

MODEL 261 REPLACEABLE PARTS LIST

(Refer to Schematic Diagram 18323E for circuit designations.)

CAPACITORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
C101	.1 μf	50 v	My	84411	601PE	C41-.1M	11
C201	500 μf	25 v	EA1	RICH	JC14-500-25-8P	C94-500M	10
C202	500 μf	25 v	EA1	RICH	JC14-500-25-8P	C94-500M	10
C203	Not Used						
C204	500 μf	25 v	EA1	RICH	JC14-500-25-8P	C94-500M	10

DIODES

Circuit Desig.	Type	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
D201	Silicon	1N645	01295	RF-14	10
D202	Silicon	1N645	01295	RF-14	10
D203	Silicon	1N645	01295	RF-14	10
D204	Zener	1N706	12954	DZ-1	10
D205	Silicon	1N645	01295	RF-14	10
D206	Silicon	1N645	01295	RF-14	10
D207	Zener	1N823	06751	DZ-36	10
D208	Silicon	1N645	01295	RF-14	10

MISCELLANEOUS PARTS

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
DS201	Pilot Lamp Bulb (Mfg. No. 313)	08804	PL-21	10
—	Pilot Lamp Holder (Mfg. No. 203CE)	72765	PL-18	
F201 (117 v)	Fuse, slow blow, 1/8 amp (Mfg. Type MDL)	71400	FU-20	
F201 (234 v)	Fuse, slow blow, 1/16 amp (Mfg. Type MDL)	71400	FU-21	
—	Fuse Holder (Mfg. No. 342012)	75915	FH-3	
J101	Binding Post, G (Mfg. No. 33-286)	08811	BP-15	2
J102	Binding Post, GND (Mfg. No. DF21GC)	58474	BP-11G	
J103	Binding Post, COM (Mfg. No. DF21BC)	58474	BP-11B	
—	Shorting Link (Mfg. No. 938-L)	24655	BP-6	
J104	Receptacle, uhf, OUTPUT, Mil. No. SO-239A (Mfg. No. 6804)	91737	CS-64	2
—	Plug, uhf, Mate of J104, Mil. No. 49190 (Mfg. No. 83-822)	02660	CS-49	
J201	Test Jack (Mfg. No. TJ300M	81453	TJ-4	10
J202	Test Jack (Mfg. No. TJ303R	81453	TJ-5	10

MISCELLANEOUS PARTS (Cont'd)

Circuit Desig.	Description	Mfg. Code	Keithley Part No.	Fig. Ref.
P201	Cord Set, 6 feet (Mfg. No. 4638-13)	93656	CO-5	
—	Cable Clamp (Mfg. No. SR-5P-1)	28520	CC-4	
S101	Slide Switch, CAL-OPERATE (Mfg. No. G326)	79727	SW-45	
S102	Rotary Switch less components, AMPERES	80164	SW-180	2
—	Rotary Switch with components, AMPERES	80164	18524B	
—	Dial Assembly, Amperes Switch	80164	17937A	
S103	Rotary Switch less components, X.01 Multiplier	80164	SW-181	2
—	Rotary Switch with components, X.01 Multiplier	80164	18463B	
—	Dial Assembly, 0-10 Readout	80164	14829A	
S104	Rotary Switch less components, X.1 Multiplier	80164	SW-159	2
—	Rotary Switch with components, X.1 Multiplier	80164	18456B	
—	Dial Assembly, 0-9 Readout	80164	14828A	
S105	Rotary Switch less components, X1 Multiplier	80164	SW-182	2
—	Rotary Switch with components, X1 Multiplier	80164	18465B	
—	Dial Assembly, 0-10 Readout	80164	14829A	
S106	Rotary Switch, POLARITY	80164	SW-189	2
—	Knob Assembly, Polarity Switch	80164	14838A	
S201	Slide Switch, 117-234 v	80164	SW-151	10
T201	Transformer	80164	TR-78	10

RESISTORS

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R101	100 kΩ	.02%, 1/2 w	WW	15909	1252	R47-100K	11
R102	1 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-1M	11
R103	10 MΩ	1%, 1/2 w	DCb	79727	CFE-15	R12-10M	11
R104	100 MΩ	1%, 2 w	DCb	80164		18087A	11
R105	10^9 Ω	1%	DCb	80164		18086A	11
R106	10^{10} Ω	1%	DCb	80164		18085A	11
R107	10^{11} Ω	1%	DCb	80164		18084A	11
R108	10^{12} Ω	1%	DCb	80164		18083A	11
R109	10 MΩ	10%, 1/2 w	Comp	01121	EB	R1-10M	11
R110	1.5 MΩ	10%, 1/2 w	Comp	01121	EB	R1-1.5M	11
R111	150 kΩ	10%, 1/2 w	Comp	01121	EB	R1-150K	11
R112	Not used						
R113	200 Ω	10%, 5 w	WWVar	71450	AW	RP3B-200	10
R114	200 Ω	10%, 5 w	WWVar	71450	AW	RP3B-200	10
R115	200 Ω	10%, 5 w	WWVar	71450	AW	RP3B-200	10

* Nominal value, factory set.

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R116	200 Ω	10%, 5 w	WWVar	71450	AW	RP3B-200	10
R117	200 Ω	10%, 5 w	WWVar	71450	AW	RP3B-200	10
R118	200 Ω	10%, 5 w	WWVar	71450	AW	RP3B-200	10
R119	200 Ω	10%, 5 w	WWVar	71450	AW	RP3B-200	10
R120	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	10
R121	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	12
R122	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	12
R123	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	12
R124	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	12
R125	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	12
R126	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	12
R127	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	12
R128	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	12
R129	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	12
R130	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	13
R131	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	13
R132	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	13
R133	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	13
R134	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	13
R135	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	13
R136	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	13
R137	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	13
R138	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	13
R139	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	13
R140	12.8 Ω	.1%, 1/2 w	WW	15909	1142	R67-12.8	13
R141	64 Ω	.1%, 1/2 w	WW	15909	1142	R67-64	14
R142	64 Ω	.1%, 1/2 w	WW	15909	1142	R67-64	14
R143	64 Ω	.1%, 1/2 w	WW	15909	1142	R67-64	14
R144	64 Ω	.1%, 1/2 w	WW	15909	1142	R67-64	14
R145	64 Ω	.1%, 1/2 w	WW	15909	1142	R67-64	14
R146	64 Ω	.1%, 1/2 w	WW	15909	1142	R67-64	14
R147	64 Ω	.1%, 1/2 w	WW	15909	1142	R67-64	14
R148	64 Ω	.1%, 1/2 w	WW	15909	1142	R67-64	14
R149	64 Ω	.1%, 1/2 w	WW	15909	1142	R67-64	14
R150	64 Ω	.1%, 1/2 w	WW	15909	1142	R67-64	14
R151	64 Ω	.1%, 1/2 w	WW	15909	1142	R67-64	14
R152	64 Ω	.1%, 1/2 w	WW	15909	1142	R67-64	14
R153	32 Ω	.1%, 1/2 w	WW	15909	1142	R67-32	12
R201	760 Ω	1%, 1/2 w	WW	01686	E-30	R58-760	10
R202	2.2 kΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2K	10
R203	10 kΩ	10%, 1/2 w	Comp	01121	EB	R1-10K	10

RESISTORS (Cont'd)

Circuit Desig.	Value	Rating	Type	Mfg. Code	Mfg. Part No.	Keithley Part No.	Fig. Ref.
R204	10 Ω	1%, 1/2 w	DCb	79727	CFE-15	R12-10	10
R205	2.2 kΩ	10%, 1/2 w	Comp	01121	EB	R1-2.2K	10
R206	10 kΩ	10%, 1/2 w	Comp	01121	EB	R1-10K	10
R207	634 Ω	1%, 1/8 w	MtF	07716	CEA	R88-634	10
R208	4.7 kΩ	10%, 1/2 w	Comp	01121	EB	R1-4.7K	10
R209	2.7 kΩ	10%, 1/2 w	Comp	01121	EB	R1-2.7K	10
R210	200 Ω	10%, 5 w	WWVar	71450	AW	RP3B-200	10
R211	*470 Ω	1%, 1/2 w	WW	01686	E-30	R58-470*	10

*Nominal Value

TRANSISTORS

Circuit Desig.	Number	Mfg. Code	Keithley Part No.	Fig. Ref.
Q201	2N1381	01295	TG-8	10
Q202	40319	02735	TG-50	10
Q203	2N1381	01295	TG-8	10
Q204	2N1381	01295	TG-8	10
Q205	2N1381	01295	TG-8	10

MODEL 2611 REPLACEABLE PARTS LIST

Description	Mfg. Code	Keithley Part No.
Plug, two req'd, uhf, Mate of Model 261, Mil. No. 49190 (Mfg. 83-822)	02660	CS-49
Reducing Adapter, two req'd, uhf, Mil. No. UG-175/U (Mfg. No. 83-185)	02660	CS-36
Shielded Cable	80164	18264B

KEITHLEY

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